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FOUNDED BY C. E. LINEBARGER

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Readers of SCHOOL SCIENCE AND MATHEMATICS keep in the front ranks of the profession by knowing what students in other departments need and use. In this issue Dr. Kinney tells why Mathematics and Science must always cooperate.

CONTENTS *for* MARCH, 1930

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SCHOOL SCIENCE AND MATHEMATICS

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COOPERATION IN THE TEACHING OF SCIENCE AND MATHEMATICS.

BY J. M. KINNEY.

This Journal bears the name SCHOOL SCIENCE AND MATHEMATICS because of the recognition of the fact that science and mathematics are closely related systems of thought. The interdependence of these two fields comes about in large part because they are both interested in variables and functionality. Thus, to carry out a scientific investigation of a phenomenon is to note variables associated with it, to collect quantitative data relative to these variables, to arrange this data in some sort of order for the purpose of displaying a relationship between them, and finally, if the investigation has a successful outcome, to find the precise character of this relationship; that is, to find the mathematical law governing the phenomenon and express it in the symbolism of mathematics.

We find a good example of scientific procedure in the work of Tycho Brahe, Kepler, and Newton relative to the behavior of the planets. The great mass of data collected from observations on the planets made over a long period of time by Tycho and Kepler led the latter to the discovery of three relationships between certain variables and known as the Laws of Kepler. From these laws as a basis of a mathematical investigation, Newton discovered a law of gravitation which held for the planets, a law which he later assumed to be the Universal Law of Gravitation.

The laws of science give rise to functions which become objects of investigation in the field of mathematics. Many times it happens that these functions arising from widely different fields

of science are "concrete" instances of an abstract mathematical function. Thus, the law of gravitation, $F=k/d^2$, the law of the intensity of illumination, $I=k/d^2$, and the resistance of a wire to the flow of electricity, $R=k/r^2$, may all be expressed in the form, $y=k/x^2$, having no reference to a concrete situation. This function may be studied in the abstract and the results of the study may be applied to any concrete situation giving rise to a function of this form.

We have been saying that science and mathematics are related. This relationship is put quite vividly in evidence in the highly developed physical sciences. Some of the more recently developed sciences, such as chemistry, biology, medicine, psychology, education, sociology, economics, anthropology, meteorology, and many others, are assuming a mathematical form. Although mathematics has developed, and is developing, within itself as a system of thought, its development has been, and is now, spurred on by the demands of the sciences. The sciences, in turn, owe their development, in large measure, to mathematical methods. Moreover, the more mathematics contributes to their development, the more do they become dependent upon it.

It follows, therefore, that people working in the scientific field are acutely conscious of the need of an extended mathematical training. Those who have not made an adequate mathematical preparation find that they are greatly handicapped in reading modern scientific literature. On the other hand many people working in the field of mathematics feel the need of keeping in touch with science. They get pleasure from seeing the applications of mathematics to concrete situations. In recent years teachers of mathematics have been pleased to see numerous articles in this Journal and elsewhere bearing on the applications of mathematics to widely separated fields of scientific investigation.

On account of this increasing reciprocal interest on the part of teachers of science and mathematics, there will no doubt be a marked increase in the enrollment of students in these fields. The percentage of increase should be greater in the department of mathematics. The large majority of students enrolling in this department will expect to get therefrom ability to do the quantative thinking of science.

The problem of making the mathematical training of the student function in the field of science presents itself for solution

more urgently than it has in the past. The solution of the problem calls for a sympathetic spirit of cooperation on the part of teachers in both fields. In the past this spirit has not been sufficiently in evidence. Teachers of science have complained that their students could not satisfactorily apply their mathematics; that not only was there but slight transfer but that also there was but little evidence of mastery of mathematical principles. This statement holds for arithmetic, algebra, and geometry. Many teachers of mathematics have replied that it was their business to teach mathematics as such, and that it was the business of the teacher of science to see that the transfer was made.

We feel that both of these attitudes are wrong and should be replaced by a sincere desire for cooperation. The proper spirit of cooperation can be brought about if teachers of science and mathematics recognize the fact that they have very much in common. They are both dealing with quantitative problems. They are both dealing with variables and their relationships. It is this notion of functionality, especially, that is of such fundamental importance in both science and mathematics. They are both interested in a symbolic language for the expression of their quantitative thoughts.

The learning product turned out in both fields will be much more satisfactory if their respective teachers can agree as to the emphasis that should be placed by each on the various phases of the quantitative problem. We feel that such an agreement can be attained. We suggest that teachers of mathematics teach the symbolic language. They should not confine their use of letters to x and y, but should use freely the letters that are used in the formulas of science. They should teach the fundamental processes and see that they are applied not only to abstract but also to concrete situations. They should stress functional thinking from the beginning to the end. They should lead students to see that an abstract functional form may have many different concrete applications. They should give students abundant practice not only in passing from the concrete to the abstract but also in passing from the abstract to the concrete.

Teachers of science should recognize the fact that their quantitative problems deal for the most part with technical situations. They should note the fact that students may be required to recall a mathematical notion or process from arithmetic, algebra, geometry, or, possibly, trigonometry and bring

it to bear on their problem. If the problem involves a functional relation, as it quite probably does, they should perhaps help the students recall the abstract form of the relationship. Above all teachers of science should be conscious of the fact that transfer for the average student takes place with difficulty even in such closely related fields as science and mathematics.

OUR MATHEMATICS DEPARTMENT GROWS.

The constantly increasing interest in mathematics, recognition of its basic value to all scientific development, and the complete reorganization of mathematics work, especially in the junior high school and elementary grades, have so stimulated production in this field that it is essential that our editorial staff be increased. After a careful survey we feel sure that the right man has been found and we take great pleasure in announcing that Mr. Charles A. Stone has accepted a place on our editorial staff and will have charge of all work connected with junior mathematics.

For this work Mr. Stone's preparation and qualifications are ideal. He received the B. S. degree from the University of Illinois in 1917, the M. A. from the University of Chicago in 1925 and is now completing the work for the Doctorate at the latter institution. His experience includes positions as teacher, assistant principal and principal in high schools. For a number of years he has been a member of the faculty of the University of Chicago high school and has been Professor of the Teaching of Mathematics in De Paul University for five years. At present he is teaching mathematics in the Laboratory Schools and offering courses in "The Teaching of Mathematics in Junior and Senior High Schools" and "Curriculum Problems in Mathematics," in the College of Education of the University of Chicago.

As an author and writer Mr. Stone is well known. In addition to many articles on the teaching of mathematics in this and other educational journals, he is the co-author of three recent books: Trigonometry, Breslich and Stone, published by the University Press; The Slide Rule, Breslich and Stone, published by the University Press; The Teaching Unit, Waples and Stone, published by Appleton and Company.

In still another line Mr. Stone has shown his ability and leadership. In the Central Association of Science and Mathematics Teacher his counsel has been valuable and his judgment good with respect to both academic and administrative questions.

His independence of thought and clear foresight have greatly assisted in promoting the interests of this organization.

SCHOOL SCIENCE AND MATHEMATICS now has a great triumvirate of mathematics editors. Professor Mills' Problem Department in each issue is keenly welcomed by scores of students, teachers and mathematicians in other professions and in industries; Dr. Kinney will continue the work with senior high school and junior college articles and text books which he has carried on for many years, but his work will now be supplemented by Mr. Stone, who will give special attention to the mathematics work of the junior high school and of the grades. They will appreciate your cooperation in keeping SCHOOL SCIENCE AND MATHEMATICS the most useful journal for teachers of these subjects.

FROM THE SCRAPBOOK OF A TEACHER OF SCIENCE.

BY DUANE ROLLER,
The University of Oklahoma, Norman, Okla.

Of course the *weight* of a body in "pounds" is very nearly equal *numerically* to the *mass* of the body; so is 1000 dollars very nearly equal *numerically* to 1001 feet! Numerical precision has very little to do with precision of thinking.—*Wm. S. Franklin and Barry MacNutt* in "*Lessons in Mechanics.*"

When we do not know the truth of a thing, it is of advantage that there should exist a common error which determines the mind of man, as, for example, the moon, to which is attributed the change of seasons, the progress of disease, etc. For the chief malady of man is restless curiosity about things which he cannot understand; and it is not so bad for him to be in error as to be curious to no purpose.—*Blaise Pascal, "Thoughts."*

Only an inventor knows how to borrow, and every man is or should be an inventor.—*R. W. Emerson.*

Mosely, of whom we may say, as the illustrious Newton said of Cotes, that had he lived we had known something.—*Edward Neville Andrade in "The Structure of the Atom." The brilliant young English physicist, Mosely, was killed by a Turkish bullet in the trenches at Gallipoli.*

The history of science is the real history of mankind.—*DuBois Reymond.*

Science is a good piece of furniture for a man to have in an upper chamber, provided he has common sense on the ground floor.—*O. W. Holmes.*

Sir David Brewster said to me that his chief objection to the undulatory theory of light was that he could not think the Creator guilty of so clumsy a contrivance as the filling of space with ether in order to produce light. This, I may say, is very dangerous ground, and the quarrel of science with Sir David Brewster, on this point, as with many other persons on other points, is that he professes to know too much about the mind of the Creator.—*John Tyndall, "Lectures on Light."*

THE NEEDS OF FRESHMEN IN THE FIELD OF MATHEMATICS.

By Luella Cole Pressey,

The Ohio State University, Columbus, Ohio.

I. *Nature of the Investigation.* This paper is the second in a series[1] that presents the results of research into the needs of freshmen in (1) reading, (2) mathematics, (3) written English (4) language, and (5) history. The method of procedure has been throughout to analyze the texts used by freshmen rather than to ask for opinions as to what items are fundamental. By reading the textbooks in mathematics, chemistry and physics, by working every problem, and by counting the frequency with which different concepts and operations occurred, it was possible to determine what is needed in the way of mathematical skills and understandings so far as the freshmen courses in these subjects are concerned. As the analyzing progressed it became evident that the preparation in mathematics might be broken up into the divisions of (a) units of measure, (b) formulae, (c) arithmetic and algebraic operations and (d) mathematical concepts. The results of the analysis will be reported under these four heads.

II. *Results.*

(a) *Units of Measure.* A count was made of the number of times each unit of measure[2] appeared in texts for the three subjects mentioned above. The items appearing five times or more per book are listed below. There were 33 other units appearing less than 5 times per book.

Some of these items would certainly be known by any freshmen—inch, foot, minute, hour, second, and cent. Others are obviously essential concepts of some course, such as dyne, erg, H. P., calorie, centigrade degree and atmosphere; one would not expect mastery of these concepts at the entrance to college work in science—except as students may have met these terms in high school courses. There remain, then, eight concepts dealing with the metric system, six common units of measure from the English system, plus meanings for "degree" and the word "pi" which is not, of course, a unit of measure but did not

[1]The other articles are appearing in current numbers of *The Journal of Higher Education*, *The Modern Language Journal*, *The English Journal*, and *The Historical Outlook*.

[2]For a careful study of the relative importance of the various units of measure, see Himebaugh, Oscar, "Conclusions of Vocabulary Studies of English and Metric Units of Measurement" in the *Educational Research Bulletin*, VIII: 175-180, April 17, 1929.

TABLE I. SHOWING THE NUMBER OF MENTIONS PER BOOK OF UNITS OF MEASURE APPEARING WITH AN AVERAGE OF FIVE TIMES OR MORE.[3]

Meter	33	Second	117
Centimeter	106	Minute	8
Millimeter	31	Hour	28
Square centimeter	14		
Cubic centimeter	52	Degree (angle)	8
Liter	23	Degree (centigrade)	112
		Degree (Fahrenheit)	10
Gram	163	Calorie	5
Kilogram	51		
		Erg	8
Atmosphere	21		
		H. P.	9
Pound	146	Dyne	13
Ton	24		
		π	8
Inch	33		
Foot	137	Cent	5
Mile	46		
Square inch	19		
Square foot	9		
Cubic foot	26		

seem to fit into the analysis anywhere else any better. These concepts would appear to be essential elements of preparation.

(b) *Formulae.* A list was made of the formula appearing in all the texts analyzed. There was a total of 172 different formulae. The problem of "reading" these formulae was considered in the previous article on the reading needs of college freshmen and will not be discussed here. In addition to understanding the meaning of a formula a student must know how to use it. The chief skill in this matter is the substitution of values for the symbols. This little trick seems to be something that many students have not learned before coming to college, as is evidenced by the fact that only 34% can find a value for x in the formula: $x = \frac{1}{2}ab^2$ when $a = 2$ and $b = 3$, and only 46% can solve the formula: $y = m^2+n^2$ when $m = 3$ and $n = 4$. The skills involved in solving the equation after the substitution are the same as those necessary for solving any equation and are included later under the analysis of skills in the texts. The total number of substitutions necessary in solving all problems in the texts, and in following through such sample problems as used formulae, was 3,010.

(c) *Arithmetic and Algebraic Skills.* A frequency count was made of the arithmetic and algebraic operations involved in both the sample problems in the text (since the student must be

[3]If texts in agriculture had been included, the units of "rod" and "acre" would have been added.

able to follow these problems through if he is to see how they are done) and in the problems assigned to the students to be solved.

TABLE II. SHOWING THE NUMBER OF TIMES *Per Book* EACH ARITHMETICAL OR ALGEBRAIC SKILL WAS NEEDED IN PROBLEM SOLVING AS DEMANDED BY TEXTS IN CHEMISTRY, PHYSICS AND COLLEGE ALGEBRA.

ARITHMETIC	
A. Integers	
1. Addition	304
2. Subtraction	147
3. Multiplication	908
4. Division	366
B. Common Fractions[4]	
1. Addition	19
2. Subtraction	7
3. Multiplication	87
4. Division (including reducing)	44
5. Inversion	12
C. Decimal Fractions	
1. Addition	265
2. Subtraction	38
3. Multiplication	403
4. Division	279
D. Special Techniques	
1. Square Root	40
2. Other Roots	9
3. Squares	133
4. Other Powers	24
ALGEBRA	
A. General Processes[5]	
1. Addition	(113)
2. Subtraction	(5)
3. Multiplication	(277)
4. Division	(43)
5. Square Root	(17)
6. Other Roots	(2)
7. Squares	(26)
8. Other Powers	(7)
B. Processes Occurring in Connection with Equations and Problems	
1. Transposing[6]	177
2. Factoring	26
3. Proportion	11

In this count a tabulation was made of *every* operation used in the problem. The analysis was made as follows:

Supposing a problem were: "A compound contains hydrogen, oxygen and sulphur. A standard weight of this compound contains

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[4]These numbers are somewhat low and those for decimals somewhat high because two of the students doing the analysis used decimals whenever a problem could be so worked while only one used common fractions from preference.

[5]These numbers refer to the manipulation of literal symbols only. Thus in collecting terms such as $6x+3x=18+9$ tabulations were made in the arithmetic section under addition of integers for $6+3$ and $18+9$, and one tabulation was made in this section for an addition of two terms involving the literal symbols. These figures are, then, already included in the totals under arithmetic, but are shown here to indicate how often the operations involved algebraic skills as well.

[6]This operation might have been tabulated as 2 subtractions (or two additions of terms having opposite signs from the one "transposed") but the process does not seem to figure in this light in the mind of the student, so it was counted separately.

2,016 grams of hydrogen, 64 grams of oxygen and the remainder is sulphur. If the standard weight of the compound is 98.016 grams, what percent of the compound is sulphur?"

The steps in solving this problem are:

(1) 2.016 plus 64. = 66.016.
(2) 98.016 minus 66.016 = 32.
(3) 32 divided by 98.016 = 33%.

In this problem there is 1 addition of decimals, 1 subtraction of decimals, and 1 division of decimals. Every problem was actually solved in getting this count of the necessary processes. The results of this painstaking analysis are presented in Table II.

It should be noted that multiplying is the outstanding need with division next and addition a close third. Subtraction is relatively unimportant.

(d) *Mathematical Concepts.* During the past five or six years at Ohio State several master's theses have been written in educational psychology dealing with the fundamental concepts needed for learning the various school subjects. As a part of the work of this type, there have been five theses[7] that dealt, in whole or in part, with the concepts of algebra, arithmetic or geometry. These studies were based upon frequency of use in high school texts, frequency of need in college sciences, and the estimates of importance from teachers of both mathematics and science. From these investigations it has been possible to make up a list of the terms which seem essential in the mastery of freshman work in these three subjects. The technical terms in arithmetic are usually pretty well mastered by the time students reach college. The terms of geometry are needed by many students not at all, inasmuch as they do not take subjects in which geometrical concepts are necessary. But there is a much more general need for certain of the fundamental concepts of algebra, in order that students may handle the formulae and equations given them in the sciences. The list of fundamental concepts as finally determined includes the following items: coefficient, unknown, numerator, denominator, exponent, square, cube, power, expression, term, root, radical, square root, expand, binomial, factor, abscissa, ordinate, graph, origin, quadratic equation, simultaneous equation, simple equation, transpose, bisect, hypotenuse, right triangle, angle.

III. *Practical Applications.*

From the data already presented, it would seem that the needs of the average freshman in mathematics include (a) a

[7]By F. A. Narragon, Maude Haley, Hazel Thrush, Zook and E. Henry.

knowledge of certain commonly appearing units of measure, (b) an understanding of the use of formulae, (c) skill in handling integers, decimal and common fractions, (d) ability to use the fundamental processes in algebra and those commonly required in solving equations and (e) the possession of certain concepts, chiefly in algebra. The test items which appear below were therefore constructed. The materials of the test were divided into two main sections, as dealing with "skills" or "concepts." There are two examples for each skill tested and students are required to get *both* examples right in order to get credit for that particular skill.

I. *From Section I on "Skills"*

(1a)[8] Add 4 1/5 to $1\frac{1}{2}$ (1b) Add $\frac{1}{2}$, 4/5 and $\frac{3}{4}$

(3a) Divide .416 by 3.2 (3b) Divide 885 by .00015

(10a) Multiply $3a^2$ by $-6a$ (10b) Multiply $-4x^2$ by $-3x^3$

$$\begin{array}{r} 3a^2 \\ -6a \\ \hline \end{array} \qquad \begin{array}{r} -4x^2 \\ -3x^3 \\ \hline \end{array}$$

(16a) Reduce $\dfrac{a+ab}{ab}$ (16b) Reduce $\dfrac{m(m-1)}{rm}$

(17a) Find the value of x: $\dfrac{x+3}{n}=5a$ (17b) Find the value of x: $\dfrac{x-m}{2}=ab$

(22a) Solve for y: $y^2=mn-z$ (22b) Solve for y: $y^2=25-3b$

II. *From Section II on Concepts*

A. From those dealing with units of measure:

5. How many pounds are there in a ton?
6. How many cubic feet are there in a cubic yard?
7. How many seconds are there in a degree?
8. How many cubic centimeters are there in a liter?

B. From those dealing with the understanding of equations:

14. Suppose you wanted to add 4 to the left side of the equation below; rewrite the equation so that it is still true.

$$x^2+4=12.$$

17. Suppose that you know the equation $3\ (a+b)=5\ (c+d)$ to be true, and that you changed the left side to read: $9\ (a+b)^2$. Finish the equation so that it will still be true.

$$9\ (a+b)^2=$$

20. What do you really do when you transpose $2a$ from one side of an equation to another? (Underline right answer.) divide the equation by $2a$ subtract $2a$ from both sides add $2a$ to both sides subtract $2a$ from one side and add it to the other.

21. When are equations simultaneous? (Underline right answer.) when they are written together when the answers are irrational when they have a common solution when they are both simple equations.

C. From those dealing with technical vocabulary:

$$\tfrac{1}{2}=\sqrt{bm} \quad (a+b) \quad \pm 2\ r^2m \quad -7mx \quad s^6 \quad (a+b+c)^5$$

23. From the above terms copy here........the coefficient of x.

---

[8] There is, of course, adequate space on the blank for working these problems.

27. From the above terms copy here........the highest power.
32. From the above terms copy here........the binomial.
34. What is the bisector of an angle? one-half the angle the longest side of the angle
    a line dividing the angle into halves
    the number of degrees in the angle.

This test was given to nearly 3000 entering freshmen in the Fall of 1929. The average score was only 22 points; the range was from 2 points to 58, of a possible total of 62[9] The test contained a total of 25 skills and 37 concepts. The average number of skills possessed well enough for the solving of two similar problems was 9, and the average number of concepts recognized, 13. Such preparation is certainly inadequate.

It is suggested that such a test as this might operate to improve preparation by pointing out to teachers in both high schools and colleges the essentials in this field. It is not an impossible ideal that all students might be brought to a sufficiently high level of accomplishment to make an almost perfect score upon this test. If the test can function as an objective basis for getting agreement between high schools and colleges as to what are the essentials, it will have served its chief purpose.

Summary

(1) This paper is the second in a series which presents the results of an extensive analysis into the needs of college freshmen in reading, mathematics, English composition, language and history.

(2) Results are presented on the frequency with which (a) units of measure, (b) formulae, (c) arithmetic and algebraic skills and (d) mathematical concepts appear in the texts used in the introduction courses in college mathematics, physics and chemistry.

(3) On the basis of this analysis the essential skills and con-concepts were selected.

(4) Items are presented from a text, which was constructed on the results of the above analysis.

(5) It is suggested that such tests might serve as objective evidence on the basis of which high school and college teachers might work out a successful articulation.

[9]A further article dealing with the practical use of this test is to appear later.

DOES THE SCIENTIST FIND OIL?

By Chas. N. Gould,
Director, Oklahoma Geological Survey, Norman, Okla.

PART III

If you have read the two preceding articles on the work of the scientist in the finding of petroleum, you are already saying, "After all, what is this all about?" "Does the scientist, that is to say, the geologist, chemist, physicist, and engineer, really help the oil man in finding oil?"

This question is pertinent. It is the one question that is asked over and over again always and everywhere. Times without number this question is put to the scientist. Can the scientist, by the use of one or the other of the methods that I have described, actually help put oil in the tank? For the oil man, being intensely practical, is not at all interested in science as such. He does not know or care anything about either the abstruse problems or the technique of any one of these sciences. All he wants is their practical application. If the scientist can help him to discover more and more oil, well and good. He will put the scientist on his pay roll. If the scientist does not help to put oil in the tank, it is just too bad for the scientist. He must hunt another job.

Perhaps the best demonstration of the utility of geology and other scientific work in the discovery of oil may be made by a comparison of oil fields. It is not always easy to determine accurately whether a certain field was or was not brought in as the result of scientific study and advice. So many different factors enter into the problem that it is often impossible to state definitely that this particular field was or was not drilled because some geologist so recommended.

226 Fields

A few years ago I made a somewhat detailed study of the problem in Kansas, Oklahoma, and northern Texas. I selected for study 226 oil fields in these three states. These fields included a number of the largest oil fields in the United States as well as many of the smaller fields. I wrote scores of letters, and interviewed many individuals, trying to get the best available data on the subject. These 226 fields were divided into three classes: first, the early fields, those that were brought in 20 to 25 years ago before oil geology was practiced; second, the

fields located by geologists in advance of drilling; and, third, the fields which were brought in by accident, or "without benefit of clergy." The results were as follows:

Early fields, 56, or 24 percent.

Brought in by accident, 13 fields, or 6 percent.

Located by geologists, 157 fields, or 70 percent.

Official figures show that in California during the decade from 1914 to 1924 thirteen major oil fields were brought in. All were located on geological advice. During the same time, 815 "wildcat" wells were drilled without geological advice. The cost of these 815 wells approximated $30,000,000, and no fields were discovered.

And I believe that the concensus of opinion of those who know is that these two examples will continue to be a fair average. More and more every year oil fields will be located by scientific advice. The easy structures, that is to say, those that can be found by reconnaissance methods or by the plane table and alidade, have largely been discovered. There is scarcely a square mile in a dozen of the states of the Plains that has not been gone over many times by this method. This in turn means that the greater number of the oil fields to be discovered in the future will be worked out by the somewhat more complicated methods, such as core drilling, micro-paleontology, and geophysical methods.

Accidents will continue to happen, as they have always happened, and occasionally a producing well will be drilled without geological advice, located by the old-fashioned oil man who does not believe in these new-fangled notions, or by the unscrupulous promoter.

But as the years go on, the number of fields so located will be fewer and fewer, and the fields brought in by the use of one or the other of the methods which I have attempted to describe will be more and more common.

In all probability, other methods in addition to those I have discussed will be found. It must be remembered that practically all the improvements in methods of oil finding have occurred within the past two decades.

The Petroleum Industry

The petroleum industry is one of the most important industries not only in the United States but in the entire world. In this country it is an eleven-billion-dollar business. It ranks

third among the industries, next to agriculture and coal.

The amount of money, in round numbers, involved in the petroleum business totals $11,300,000,000, distributed as follows:

Production	$5,000,000,000
Refining	3,000,000,000
Transportation	1,800,000,000
Marketing	1,500,000,000

The world production of oil from 1859 to date is about 17 billion barrels.

Of this the United States has produced over 12 billion barrels.

California and Oklahoma have each produced nearly 3,000,000,000 barrels and Texas almost 2,000,000,000 barrels.

Only Seven Months' Supply on Hand

At the present time there is enough oil in storage in the United States to last between 200 and 250 days. If the oil wells of this country would suddenly cease producing oil on March 1, 1930, we have on hand only enough oil, counting crude stocks and refined products, to run the motor cars until some time in August or September. After that we would have to walk.

It is absolutely essential that we continue to find more and more oil unless the balance of our modern civilization breaks down. Can you imagine a motorless, gasolineless age? Synthetic gasoline from coal, or the derivation of power from alcohol may, in the future, prove to be practical, but at the present these things are but roseate dreams. The ingenuity of man will eventually solve these problems, but it is rather unlikely this will happen within the experience of any one now living.

Therefore, it is up to the scientist to continue to devise new methods of oil-finding, and to continue to perfect his technique in methods now in use, to the end that continued streams of oil may flow into the tanks which, when refined and made into gasoline, will continue to drive our motor cars and help keep alive our civilization.

"Our work should challenge in appeal the lure held for young people by a circus. When I say circus I mean any competitor of the school for youths' interest—the dance, the theatre, football, society, and in a larger sense, business, industry, and getting rich. The school's rivals have forged ahead and taken more than is their right, while the school has lagged behind and taken less."—*John G. Bowman, Chancellor of the University of Pittsburgh.*

STATISTICAL APPLICATIONS OF ELEMENTARY MATHEMATICS.

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Attempts have been made for a long time to subject the laws governing vital phenomena and the phenomena of human society to a mathematical treatment comparable in definiteness with that which is traditional in such "exact" sciences as physics and astronomy. The branch of mathematics known as the theory of probability has been conspicuously useful in giving these attempts a measure of success. New fields have been opened up to quantitative investigation, in biology, psychology, education, medicine, and economics, by the development in recent decades of new statistical methods, notably by Professor Karl Pearson and his followers. From the very fact that the initial steps are tentative, and that mathematical deduction is not to be carried too far in any one direction on the basis of the new methods until the first conclusions have been checked by fresh data, it results that there is much work to be done with processes that are quite elementary on the mathematical side. It is the purpose of this paper to show how some of the most familiar facts of high-school mathematics are adequate for the proof of important theorems in statistics. While it contains nothing that is not to be found in substance in the standard text-books[1] it is arranged with the aim of bringing out as clearly as possible the elementary character of the reasoning.

The rules of algebra can be applied with particular effectiveness in connection with the principle of least squares, and the derivation of various important formulas from it. A full appreciation of the significance of this principle, as well as of the limitations of its applicability in particular problems, is to be gained from extended study and experience rather than from any brief theoretical argument; but its power is largely due to the fundamental simplicity of the mathematical relations which arise out of it.

One of the simplest illustrations is the connection of the least-square principle with the definition of an arithmetic mean. To specialize the problem in the direction of the utmost possible

[1]In particular, most of the discussion of the correlation coefficient is merely a presentation of the method of the corresponding passage in Yule's *Introduction to the Theory of Statistics* pp. 170-177; but if it convinces the reader that the essential ideas can be readily understood without previous technical study of theoretical statistics or advanced mathematics, it wil have served its purpose.

simplicity suppose a, b, c are any three given numbers. Their average, or arithmetic mean, is $\frac{1}{3}(a+b+c)$. On the other hand, let the following problem be proposed: To find a single number x which shall serve as a general representative of the three numbers a, b, c, with as close a degree of approximation as possible, the last requirement being interpreted to mean specifically that the sum of the squares of the errors, the expression

$$(a-x)^2+(b-x)^2+(c-x)^2,$$

shall have the smallest possible value. (The choice of the *square* rather than some other power of the error is justified by the result, and by the considerations that underlie the use of the method of least squares generally. Minimizing the sum of the first powers of the errors, taken without regard to algebraic sign, would lead to another important average, the *median;* although the median sometimes has advantages over the arithmetic mean, its mathematical theory is essentially less simple.) Let the arithmetic mean of a, b, c be denoted by m; in other words, let m be defined by the equation

$$m=\tfrac{1}{3}(a+b+c).$$

It follows at once from this equation that

$$(a-m)+(b-m)+(c-m)=a+b+c-3m=0.$$

If $a-x$ is written in the form

$$a-x=(a-m)+(m-x),$$

expansion of the square of the last expression by the rule for squaring a binomial gives

$$(a-x)^2=(a-m)^2+2(a-m)(m-x)+(m-x)^2.$$

Similarly,

$$(b-x)^2=(b-m)^2+2(b-m)(m-x)+(m-x)^2,$$
$$(c-x)^2=(c-m)^2+2(c-m)(m-x)+(m-x)^2.$$

By addition of these equations, and suitable combination of the terms on the right,

$$(a-x)^2+(b-x)^2+(c-x)^2=(a-m)^2+(b-m)^2+(c-m)^2$$
$$+2(m-x)[(a-m)+(b-m)+(c-m)]+3(m-x)^2.$$

But the expression in brackets is equal to zero, as was pointed out above, so that

$$(a-x)^2+(b-x)^2+(c-x)^2$$
$$=(a-m)^2+(b-m)^2+(c-m)^2+3(m-x)^2.$$

In the right-hand member of the last equation, the only term that depends on x—the only term that can be varied by varying x—is $3(m-x)^2$, which reduces to zero if $x=m$, and is positive for all other values of x. So this term, and consequently the whole expression, is reduced to its minimum value by taking

$x=m$. *The solution of the least-square problem is given by the arithmetic mean.*

To deal with the average of an arbitrary number of given quantities, instead of just three, suppose there are n such quantities, and let them be denoted by $X_1, X_2, \ldots, X_n$, instead of a, b, c. The problem then is to find a number x to make $\Sigma(x-X_k)^2$ as small as possible; the sign Σ, wherever it occurs, here and later, means that the terms indicated are to be formed for each value of k from 1 to n, and added together. The above proof, repeated with the modifications that are obvious, shows that the minimum is reached when x is the arithmetic mean of the X_k's, $(1/n)\Sigma X_k$.

Another important problem of least squares is the following: Suppose two sets of n quantities each are given, $X_1, X_2, \ldots X_n$ and $Y_1, Y_2, \ldots, Y_n$. It is convenient for various purposes, and important for certain definitions, to deal with the deviations of the numbers of each set from the corresponding arithmetic mean, instead of the given numbers themselves. Let $\overline{X}$ be the mean of the X's, and $\overline{Y}$ the mean of the Y's,

$$\overline{X}=(1/n)\Sigma X_k, \qquad \overline{Y}=(1/n)\Sigma Y_k,$$

and let $x_k=X_k-\overline{X}$, $y_k=Y_k-\overline{Y}$, for each value of k from 1 to n. It follows from these definitions that $\Sigma x_k=\Sigma y_k=0$. The problem then is to find a number b so that $\Sigma(y_k-bx_k)^2$ shall be as small as possible, or in other words to determine the coefficient b so that bx_k shall give the best possible approximation to y_k, when the sum of the squares of the individual differences y_k-bx_k is considered to measure the error of the approximation for the set of numbers as a whole. It will be shown that the solution is obtained by taking

$$b=\frac{\Sigma x_k y_k}{\Sigma x_k^2}.$$

To bring out the significance of the question more clearly, let the x's and the y's, and more specifically the association of each particular x_k with the corresponding y_k, be represented graphically by plotting the n points (x_k, y_k) with respect to a pair of rectangular coordinate axes. The requirement is to choose the line $y=bx$, among all lines through the origin, so that the sum of the squares of the distances of the n points from it, *measured parallel to the y-axis* (not perpendicular to the line), shall be a minimum. While the geometric formulation is instructive, however, the actual solution will be algebraic.

For the moment, let Σx^2_k, $\Sigma x_k y_k$, Σy^2_k be denoted by A, B, C respectively. Then, for any value of b,

$$\Sigma(y_k - bx_k)^2 = \Sigma y^2_k - 2b\Sigma x_k y_k + b^2 \Sigma x^2_k$$
$$= C - 2Bb + Ab^2.$$

The last expression is the same as $(1/A)(AC - 2ABb + A^2b^2)$, which can be further rearranged in the form

$$\frac{1}{A}(AC - B^2 + B^2 - 2ABb + A^2b^2) = \frac{1}{A}[(AC - B^2) + (B - Ab)^2].$$

The x's and the y's, and consequently A, B, C, are to be thought of as given quantities. Of course A and C, being sums of squares, are positive, while B may be positive, negative, or zero, according to circumstances. (The trivial case in which all the x's are zero, or all the y's are zero, is ruled out.) In the last form of representation of $\Sigma(y_k - bx_k)^2$, the only thing that can be varied by varying b is the term $(B - Ab)^2$. Being a perfect square, this is necessarily positive or zero; it is reduced to a minimum by making

$$B - Ab = 0, \qquad b = \frac{B}{A} = \frac{\Sigma x_k y_k}{\Sigma x^2_k}.$$

The question can be modified by seeking to minimize the quantity $\Sigma(x_k - by_k)^2$, instead of $\Sigma(y_k - bx_k)^2$. Algebraically this problem differs from the other only by the interchange of the letters x and y, and the value of b giving the solution is

$$b_1 = \frac{\Sigma x_k y_k}{\Sigma y^2_k}.$$

In distinction from this b_1, the b previously obtained will be denoted by b_2. From the point of view of the geometric representation, the line represented by the equation $y = b_2 x$ is called the *line of regression of y on x*, and the line $x = b_1 y$ is the *line of regression of x on y*. The latter is characterized by the fact that the sum of the squares of the *horizontal* distances of the plotted points from it is a minimum. The numbers b_2 and b_1 are the corresponding *coefficients of regression.*

A quantity associated with the regression problem is the *coefficient of correlation* of the sets of numbers x_k and y_k, commonly denoted by the letter r. It is equal to $\sqrt{b_1 b_2}$, the geometric mean of the regression coefficients, and its value is given by the equation

$$r = \frac{\Sigma x_k y_k}{\sqrt{(\Sigma x^2_k)(\Sigma y^2_k)}}.$$

It is at the same time, by definition, the coefficient of correlation of the original sets of numbers X_k and Y_k. That is to say, the coefficient of correlation of any given sets of numbers is defined in terms of their deviations from their respective arithmetic means, or else by some equivalent expression. One such alternative formula will be further discussed below.

An important property of the correlation coefficient, the fact that its numerical value can never exceed 1, comes out very readily from the formulas that have already been used. It was seen that a certain expression obtained as a representation of $\Sigma(y_k - bx_k)^2$ was reduced to a minimum by making $B - Ab = 0$. The value of the entire expression is thereby reduced to

$$(1/A)(AC - B^2).$$

But $\Sigma(y_k - bx_k)^2$ is a sum of squares, and even at its minimum is necessarily positive or zero. As A is positive, this means that $AC - B^2$ must be positive or zero, which is the same thing as saying that B^2 is not greater than AC. But the equation defining r can be written in the form $r = B/\sqrt{AC}$, and the fact that B^2 cannot exceed AC means that $r^2 = B^2/AC$ cannot exceed 1. Hence the value of r itself is between -1 and $+1$, or equal to one of these extreme values as a limiting case.

The expression obtained for the minimum value of $\Sigma(y_k - bx_k)^2$ is of importance in itself. The quantity $\sqrt{(\Sigma x^2_k)/n}$, or $\sqrt{A/n}$, which may be denoted by σ_1, is the *standard deviation* of the numbers x_k, or of the numbers X_k, and similarly $\sigma_2 = \sqrt{(\Sigma y^2_k)/n} = \sqrt{C/n}$ is the standard deviation of the y_k's or of the Y_k's. The quantity

$$\sigma_{2\cdot 1} = \sqrt{(1/n)\Sigma(y_k - b_2 x_k)^2},$$

in which b has been given the value of the regression coefficient b_2, is the *standard error of estimate of y in terms of x*. From the definition of $\sigma_{2\cdot 1}$ it follows that

$$n\sigma^2_{2\cdot 1} = \Sigma(y_k - b_2 x_k)^2 = \frac{1}{A}(AC - B^2) = C - \frac{B^2}{A} = C(1 - \frac{B^2}{AC})$$
$$= C(1 - r^2) = n\sigma^2_2(1 - r^2),$$

so that finally

$$\sigma^2_{2\cdot 1} = \sigma^2_2(1 - r^2).$$

Somewhat informally, this equation may be said to measure the extent to which the dispersion of the y's can be reduced by subtraction of a suitable multiple of the x's; if $r = 0$, $\sigma_{2\cdot 1}$ is the same as σ_2, while otherwise $\sigma_{2\cdot 1}$ is less than σ_2 in the ratio of $\sqrt{1 - r^2}$ to 1.

It has been mentioned that the formula given for r above is not the only one. Another, which is sometimes preferable in use, though less simple in appearance, is

$$r=\frac{n\Sigma X_kY_k-(\Sigma X_k)(\Sigma Y_k)}{\sqrt{n\Sigma X^2_k-(\Sigma X_k)^2}\sqrt{n\Sigma Y^2_k-(\Sigma Y_k)^2}}.$$

Its advantage lies in the fact that it is expressed directly in terms of the original quantities X_k, Y_k, and does not require the explicit calculation of the arithmetic means and the deviations from them, a process which may introduce inconvenient fractions. The proof that both formulas represent the same quantity is once more a matter of elementary algebra.

Since $x_k=X_k-\overline{X}$, $y_k=Y_k-\overline{Y}$, it follows that

$$\Sigma x_ky_k=\Sigma(X_k-\overline{X})(Y_k-\overline{Y})=\Sigma X_kY_k-\overline{Y}\ \Sigma X_k-\overline{X}\ \Sigma Y_k+n\overline{X}\ \overline{Y};$$

$\overline{Y}$ and $\overline{X}$ are taken out as common factors from the second and third summations in the right-hand member, while the last term results from the fact that the product $\overline{X}\overline{Y}$, independent of the subscript k, is repeated n times. Substitution of the values $\overline{X}=(1/n)\ \Sigma X_k$, $\overline{Y}=(1/n)\ \Sigma Y_k$, transforms the right-hand member into

$$\Sigma X_kY_k-\frac{1}{n}(\Sigma X_k)(\Sigma Y_k)-\frac{1}{n}(\Sigma X_k)(\Sigma Y_k)+\frac{1}{n}(\Sigma X_k)(\Sigma Y_k),$$

which reduces to

$$\Sigma X_kY_k-\frac{1}{n}(\Sigma X_k)(\Sigma Y_k).$$

Similarly,

$$\Sigma x^2_k=\Sigma X^2_k-\frac{1}{n}(\Sigma X_k)^2,\qquad \Sigma y^2_k=\Sigma Y^2_k-\frac{1}{n}(\Sigma Y_k)^2,$$

the distinction between ΣX^2_k and $(\Sigma X_k)^2$ being of course that one is the sum of the squares of the X_k's and the other is the square of their sum. By insertion of these values in the earlier expression for r, and multiplication of numerator and denominator by $n(=\sqrt{n}\cdot\sqrt{n})$ to clear of fractions,

$$\frac{\Sigma x_ky_k}{\sqrt{(\Sigma x^2_k)(\Sigma y^2_k)}}=\frac{n\Sigma x_ky_k}{\sqrt{n\Sigma x^2_k}\sqrt{n\Sigma y^2_k}}=\frac{n\Sigma X_kY_k-(\Sigma X_k)(\Sigma Y_k)}{\sqrt{n\Sigma X^2_k-(\Sigma X_k)^2}\sqrt{n\Sigma Y^2_k-(\Sigma Y_k)^2}}.$$

Other modifications of the formula, sometimes preferred to either of those given, are similarly obtained.

These are only the beginnings of a treatment which could be worked out at much greater length if space permitted. For the definition of a *coefficient of correlation by rank*,

$$\rho = 1 - \frac{6\Sigma D^2_k}{n(n^2-1)},$$

and a proof that it is merely the result of applying the formula for r to the numbers designating the relative positions of the X's when they are arranged in order of magnitude and the corresponding rank numbers for the Y's, for a discussion of partial correlation coefficients, for the more extensive use of geometric representation, with applications of plane and spherical trigonometry, and for further developments of the theory, the reader is referred to papers by the present writer and by Professor Huntington in the American Mathematical Monthly and elsewhere, and to the text-books[2]. It is not asserted that all will be easy reading, or that any algebraic devices can wholly remove the difficulties that are inevitably encountered in dealing with a complex array of quantitative relations. There is no royal road to the remoter parts of the subject, for the mathematician or for anybody else. But the student who has mastered the algebraic content of the fundamental formulas will have taken an important step toward acquiring what Lord Bryce calls "the special skill and knowledge needed to distil from rows of figures the refined spirit of instruction."

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[2]See, for example, D. Jackson, The Algebra of Correlation, American Mathematical Monthly, vol. 31 (1924), pp. 110-121; The Trigonometry of Correlation, American Mathematical Monthly, vol. 31 (1924), pp. 275-280; The Relation of Statistics to Modern Mathematical Research, Science, vol. 69 (1929), pp. 49-54; E. V. Huntington, Mathematics and Statistics, with an elementary account of the correlation coefficient and the correlation ratio, American Mathematical Monthly, vol. 26 (1919), pp. 421-435; G. U. Yule, An Introduction to the Theory of Statistics, already cited.

"INTELLECTUAL IMMORALITIES."

Twenty-five kinds of "intellectual immoralities" have been enumerated by Milton Fairchild, director of the Character Education Institution of Washington, D. C., in an effort to constitute a verification of plans for human welfare. A method to determine those in the individual has been worked out on scientific lines by the institution. Among these "intelligent immoralities" are the following:

Carelessness in observations, "sloppy work."

Slovenliness in logic, fantastic explanations.

Confusing opinions with knowledge.

Contentment with "discussion."

Wavering interest, flitting attention, attracted by peculiar superficialities.

Opposition to proof of another's theories because of jealousy.

Impatience, unwillingness to proceed step by step through a research.

Indulgence in dense verbiage for the sake of appearing superlearned.

Popularizing tentative generalizations for the sake of personal publicity.

Resort to the authorities, or to sarcasm and ridicule, against data, arguments and verifications.

THE COSMIC RAY IN HIGH SCHOOL PHYSICS.

By H. Emmett Brown,

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In his admirable little book, "Fundamental Concepts of Physics," Paul R. Heyl shows how, in the nineteenth century, the concept of energy was gradually developing from the "imponderables of the previous century which were taken one by one from the domain of matter to form a new kingdom by themselves" and how, as a result of the work of such men as Maxwell, Faraday, Oersted and others, in showing the relationships between the phenomena from different portions of physics, this new concept came to assume a place of as great importance as that occupied by the earlier notion—the concept of matter. The author then proceeds to trace the enrichment of this concept thru the discovery of new phenomena and the development of new theories for their adequate explanation. Finally, he says, (p. 102), "We have seen how the nineteenth century correlated and combined the separate concepts which it inherited from the eighteenth century, and introduced the immaterial concept of energy; and how the twentieth century, in that brief portion which has as yet elapsed, has completed the scheme of correlations, even reducing matter itself to a manifestation of energy. Energy thus becomes the sole concept of modern physics; . . . ."

This is not the place, and space does not permit the detailed setting forth of the point of view of many teachers of high school physics who firmly believe, with Heyl, that the entire high school physics course should be developed from this notion of physics as the science of energy. A rather sketchy development of their point of view is necessary, however, as without it, any use of the cosmic ray, beyond the merest mention, is probably incomprehensible and indefensible.

In the first place then, physics is the science of energy and man's interest in it is primarily one in the efficient transformation of this energy. Now almost all energy on the earth, can be traced back to the sun which is radiating it in enormous amounts in the form of electromagnetic waves, but at a terrible price to itself since this radiation is accomplished at the expense of a loss of mass of about four million tons per second. Bear this fact well in mind, as it comes up again with renewed significance, in connection with the final conclusions as to the nature of the cosmic

rays. The radiated energy of the sun is composed of two types, both electromagnetic. One is a band of waves of a relatively small wave length spread, which are visible to the eye; the other type is invisible, composed of waves both longer and shorter in wave length than the first group. The longer waves, in particular, are of the utmost importance to man in that they are waves of radiant heat, the absorption and transformation of which makes life possible on the earth. And then, still further in the direction of longer waves, are the Hertzian waves, covering relatively a large portion of the spectrum.

It is with the other end of the spectrum however, that we are primarily interested in this discussion. Only recently a scientist has succeeded in showing that the ultra-violet rays, such as are found in sunlight, may be extended into the X-rays. This, then is the picture of the electromagnetic spectrum—a wave band of approximately 55 octaves, energy in its various forms, much of it radiated directly by the sun. Much of the physics course takes its departure directly from this concept. It, together with the various theories as to the structure of matter, serve the double purpose of explaining the phenomena of physics and integrating the various divisions, too often taught as uncorrelated and unrelated units.

The question has naturally been raised as to whether there might not be waves, both longer, and others shorter, than those included in the electromagnetic spectrum indicated above. If for no other reason, the story of the Cosmic Rays is of interest as the answer, probably final, to the question of what lies beyond the short gamma rays.

It was not until the year 1903 that any mention of a penetrating radiation appears in the literature, although it is highly probable that evidences of the rays had been observed in connection with other ionization phenomena, but not recognized as a distinct radiation. In that year two different groups of investigators—Rutherford and Cooke on the one hand, and McLennan and Burton on the other, both writing in the Physical Review, report a radiation of great penetrating power, the first group stating that it would pass thru 5 cm. of lead with a loss in ionizing strength of only 30%. Both groups thought the radiation emanated from some radioactive materials in the walls of the room. However, McLennan and Burton commented that all of the effects produced could not be due to this alone, but that part must be produced by some penetrating radiation of nature and origin unknown.

In spite of the challenge that this statement would seem to carry and even although the method for verifying the tenability of Rutherford and Cooke's hypothesis as to the origin of these rays seemed rather obvious, it was apparently several years before any further work was done along this line. Obviously, if these radiations have their origin in the earth's crust, they should decrease in intensity with elevation. However numerous balloon trips during the years 1910 to 1915, made by Goeckel, Hess, and Kolhorster failed to reveal any such decrease, the former two finding the radiations of practically constant strength. Kolhorster, whose work was apparently the most carefully performed, by ascending to heights greater than those to which Goeckel and Hess went, found an actual increase which, after passing a certain point varied directly with the elevation, thus effectively disproving the theory of the earthly origin of the radiations. To Kolhorster, in particular, must go the credit for the first serious study of the rays, although he attributed a seasonal periodicity and directional effect to them, that the most careful experimentation by later workers has failed to reveal. The method for detecting and studying the radiations employed by these German scientists was substantially that used by Millikan in his aerial investigations, save that personal flights were rather more common in the earlier work, and hence details need not be given at this point.

Again there appears a hiatus in the cosmic ray history, for it was not until 1922 that Millikan, whose name and that of his associates, are outstanding in the final and most important phase of the work, appears on the scene. In the summer of that year we find him sending up sounding balloons, with electroscopes attached, to heights as great as 15.5 kilometers, at which point 88% of the earth's atmosphere is left behind. Ingeniously, he employed two balloons, the extra one serving the double purpose, after the first had burst, of checking the too rapid descent of the recording electroscope, and of attracting the attention of someone who might return the instrument. The electroscope used, a modification of the more or less standard instrument used by the German scientists, and identical in its major characteristics with those used by Millikan in all his later work, merits description. The charged element consisted of two quartz fibers, sputtered with platinum, fastened at the upper end to a copper tube and at the lower to a bow of plain quartz fiber, by adjusting which the sputtered fibers might be regulated. In

actual use, the fibers, mounted in an air-tight case, capable of withstanding a considerable internal air pressure, were deflected by charging with a battery of several hundred volts. The record of the discharge of the fibers, occasioned by the penetrating radiations, was obtained by letting a small amount of light enter thru a small vertical slit, casting a shadow of the fibers on a photographic film moved slowly along by clockwork. A means for recording temperature was also provided. The results obtained by these means were substantially in agreement with those of Kolhorster in showing the increase in ionizing strength with altitude, but the observed ionizing effect was only about 25% of that predictable from the German physicist's data.

The following summer found Millikan, with an associate, Otis, at work again on the problem. They were at the top of Pike's Peak, where a radiation of local origin, very little harder than the gamma rays from RaC, did much to confuse matters until a lead shield of sufficient thickness to insure their absorption was employed. The difference in penetrating power between the true cosmic rays, when finally isolated thru the use of the shield, and these softer local rays, together with the other work up to this point, enabled them to say that if penetrating radiations exist they must have an absorption coefficient of .25 or less in order to produce the 2 ions per cc. per sec. noted at sea level. Surely a temperate enough statement in view of the large expenditure of work and time that had already been made on the problem. (Note that the absorption coefficient and penetrating power vary inversely—radiations of the highest penetrating power have the smallest coefficient.) In other words these rays were shown to be of a character different from any suggested up to the time of Millikan's statement (1923).

Two years later, Millikan and G. H. Cameron, who was the associate in all the later work, started what proved to be the beginning of the final phases of the investigation. In order to avoid the radioactivity that had troubled them at Pike's Peak and elsewhere, they decided to sink their electroscopes in the clear waters of high, snow-fed lakes. At both Muir and Arrowhead Lakes, when allowance was made for the lower altitude and hence greater depth of the latter in the atmospheric ocean, results were uniform in showing that the rays would penetrate at least 73 feet of water or the equivalent of 6 ft. of lead.[1] When it is recalled that the most penetrating X-rays will only pierce

[1]Later work revealed bands of waves in the cosmic rays of an even greater penetration.

1-2 inch of lead, some idea of the extreme power of the radiations may be gained. As the result of computations using the Compton-Ahmad formula for mass obsorption coefficients, and employing the values for the coefficients of from .18 to .30, obtained experimentally, they were able to assert that the wave lengths must vary between .000634 and .00038 Angstrom units. The frequency of these rays was about 50 times that of the shortest gamma rays and corresponded closely to the energy involved in the simple capture of an electron by a proton. In Millikan's own words, "the cosmic rays are probably, therefore, not degenerated waves of higher frequency, but are rather generated by nuclear changes having energy values of 19,000,000 to 34,000,000 volts." The fastest Beta ray on record has an energy of 9,500,000 volts.

The problem of the real nature of the origin of the radiations still remained to be settled. The scientist's own ideas, stated above, gives his theory of the probable method of production of at least part of the cosmic rays. There still remained much work to be done, however.

Other problems also confronted the two investigators. In 1926, Eddington and C. T. R. Wilson hazarded the opinion that the rays might be due to "run-away" electrons likely to be present in severe electrical storms. Kolhorster's belief that they exhibited a seasonal periodicity, and particularly a directional effect, with the rays from the general direction of the Milky Way of the greatest concentration, has already been noted.

Accordingly, with the idea of testing these beliefs and of further checking the work in North America against that in another continent, the two scientists betook themselves to Lake Miguilla in the high Andes. The ionization values obtained here agreed completely with those obtained in North America for the same altitude and repeated readings taken during thunderstorms failed to reveal the increase that Eddington and Wilson's theory would require.

In order to test Kolhorster's directional belief, they transferred their activities to the Caracoles Tin Company's mine, at an altitude of 14,500 ft., where nearby mountain peaks blotted out the Milky Way for about 4 1-2 hours on several successive nights. The data failed to disclose any significant difference between readings taken when the Milky Way was at its maximum or when radiations from that source were eclipsed by the mountains.

In their final field work, Millikan and Cameron, back again at some of the lakes used in earlier investigations in this country, thru the use of improved electroscopes, were able to prove the existence of at least three separate and distinct wave bands in the cosmic rays, corresponding to absorption coefficients of .35, .08 and .04 respectively. The shorter wave lengths run as low as .00008 Angstrom units and correspond to a generating potential of 150,000,000 volts. As a result of this work also, they were able to show thru computations given in the original papers, but probably not worth duplicating here, that the cosmic rays furnish about 3.07×10^{-4} ergs per sq. cm. per sec. to the earth. It is known that the sun and stars supply us energy to the value of 3.02×10^{-3} ergs per sq. cm. per sec. (Of this amount, the quantity furnished by the stars constitutes a negligibly small part.) In other words, the cosmic rays radiate energy to the earth in a concentration roughly 1/10 of that received from the sun. Surely a not inconsiderable quantity of energy.

The early workers on this mysterious radiation had naturally attempted to explain its origin and nature in terms of known sources of penetrating radiations, the radioactive substances. Three other theories of the origin of the rays were also held at one time or other. Stated briefly these were: that they might be the result of some sort of step-by-step atomic building-up process; due to the annihilation of the hydrogen atom; some form of black-body radiation.

In their final reports Millikan and Cameron show the impossibility of all these theories and set up an alternative explanation which apparently overcomes the objections that may be leveled at all the others.

A radioactive substance was impossible for two reasons. In the first place, because of their abundance, the rays would need to be a radiation from some very common substance. No radioactive elements are at all common. Secondly, applying the Einstein frequency equation and the Dirac formula, it was possible to show that the highest energy that can be emitted in each act of ejection of an alpha particle is about 10^{-5} ergs, corresponding to an energy of about 7,700,000 volts. A radiation of this penetrating power would pass through 4 meters of water before being absorbed. Cosmic rays will penetrate 70 meters. Similarly it may be shown that any step-by-step building up process of atoms would result in rays that could penetrate no more than 8 meters of water, still far short of the cosmic ray penetration.

The hydrogen atom annihilation theory was easily disproved, as rays from such a source would be homogeneous and cosmic rays were shown to be composed of at least three distinct wave bands.

The black-body radiation theory was impossible on a number of counts, the most convincing of which is probably that it would be an impossibility for a black body to produce radiations of such penetration, particularly in view of the fact that the cosmic rays come from interstellar space, where temperature conditions are not conducive to black body radiations.

Having disposed of the earlier attempts at an explanation, let us follow the steps that Millikan and Cameron followed in developing their own theory, by exploring the possibility that the rays may result from the building up of atoms from other, and simpler atoms. Thus, if we consider that helium may result from the combination of four hydrogen atoms, it may be seen that an accompanying loss of mass of about .029 grams (According to the Einstein equation and the findings of Aston, it would be $4\times1.00778-4\times1.0054$.) would result. Then the radiant energy resulting from this loss of mass would be given by the expression $\frac{.029\ c^2}{\text{Avogadro's number}}$ where c is the speed of light. Substituting the values in the expression we have $\frac{.029\times9\times10^{20}}{6.062\times10^{23}}$ or 4.3×10^{-5} ergs. In his final paper, published in the October, 1928, issue of the Physical Review, Millikan develops the truth of the above equation, and shows further, that the frequency of a radiation is obtained from the equation E_1-E_2 equals $h\nu$, or ν equals $\frac{E_1-E_2}{h}$. Substituting the value for the numerator obtained above, and the standard value for h (Planck's constant), we obtain, ν equals $\frac{4.3\times10^{-5}}{6.547\times10^{-27}}$ or 6.57×10^{21}. This corresponds to a wave length of .0046 Angstrom units. Using the Dirac formula, and the wave length given above, an absorption coefficient of .30 was obtained. In the same way, in the case of nitrogen, an absorption coefficient of .086, and for oxygen, one of .074 were obtained. The average of these last two gives a mean for air of about .080, which agrees completely with the observed coefficient for the second wave band of the cosmic rays.

If silicon be considered as produced from hydrogen, in the

same way, an absorption coefficient of .041 is obtained. The observed coefficient for the third wave band in the cosmic ray was .04. Thus the results obtained by assuming the synthesis of the atoms of these common elements from those of hydrogen, show absorption coefficients for radiations that should be produced in the act of creation, that are in agreement with those observed for the different wave bands found in the cosmic rays.

Working out a similar computation in the case of iron, the absorption coefficient obtained is .019. For whatever the reason, no band of cosmic rays have been identified which have this coefficient. It is, however, quite possible that there are rays of this penetration that have eluded the investigators to date.

The final picture, suggested by Millikan and Cameron, that should be ours is of an energy radiation which comes to us with equal strength from all directions from interstellar space. Unaffected by the season of the year, or the position of the heavenly bodies, these rays are continually supplying to the earth 1-10 as much energy as does the sun itself. Because of the evidence of the spectroscope, we know that there are electrons and protons in interstellar space. We know furthermore that the high temperatures found in stars are inimical to, and low temperatures (approaching absolute zero) are favorable to the synthesis of atoms. That the synthesis of the atoms of helium, oxygen, silicon, and iron from hydrogen, or possibly in the case of the latter two from helium, does occur, the cosmic rays are apparently full and complete proof. Millikan goes even further and suggests the existence of a cycle which, beginning with an act of atomic creation, next contemplates these atoms aggregating into stars which, in turn, as in the case of our own sun disintegrate, supplying energy to our earth and other heavenly bodies.

The complete proof of the truth of this hypothesis can, perhaps, never be demonstrated. It does, however, in spite of Eddington[2] represent a fascinating picture. Surely these rays are rightly called since they lead us to perceive a cycle that is truly cosmic in its significance.

It has been suggested earlier in this article that the high school

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[2]A. S. Eddington, Nature of the Physical World, Macmillan, 1928, p. 85: "But the Phoenix complex is still active. Matter, we believe, is gradually destroyed and its energy set free in radiation. Is there no counter process by which radiation collects in space, evolves into electrons and protons, and begins star building all over again? This is pure speculation and there is not much to be said on one side or the other as to its truth. But I would *mildly criticise* (italics mine) the mental outlook which wishes it to be true."

Millikan is apparently not concerned, or does not care to hazard a surmise as to the reason for the presence of electrons and protons in interstellar space. He is content to show that they are there. He does not hesitate, however, to suggest the completion of the cycle from that point.

physics course might take its departure from the energy concept. The question naturally to arise next is just how the story of the cosmic ray fits into such a course. The generalized answer is obviously, "To the extent that it contributes to the realization of the major objectives of the course."

Specifically there are a number of ways in which this story does contribute. Among these are:

1. The concept that all mass is fundamentally a form of energy is enriched since the cosmic rays are produced as a result of an atomic synthesis in the process of which mass is lost and energy produced and radiated.

2. It presents a picture of the atom from a different angle than that usually employed. In the study of radioactivity, the atoms of the heavier elements are shown as disintegrating, in the course of which act alpha and beta particles and gamma rays are given off. The question naturally arises as to whether the process may not be to some degree reversible. The story of the cosmic ray is the answer.

3. We stress the sun as the source of useful energy, in our physics teaching. The cosmic ray, in showing how energy may be produced at the expense of mass, furnishes another experience tending to enrich that concept.

4. It helps to round out and complete the picture of the electromagnetic wave band of energy which is developing in the pupil's minds throughout the year. It does this in at least three ways: first, by showing a portion of the band beyond that usually depicted; secondly, by stressing the similarity of the production of cosmic and sun rays; thirdly, by stressing the increased penetration that the very high frequency of these rays, according to the provisions of the quantum theory, would necessarily have.

5. It helps to give an appreciation of the amount of energy furnished by the sun, mainly, and the stars, since the cosmic rays, themselves, are radiating energy at a rate 1-10 as great as that of the other sources.

6. On practically every list of general objectives for science courses, there appears that one, generally titled the "scientific attitude." No one knows how to teach the appreciation of the scientific method, unless it be thru the study of typical cases. The story of the cosmic ray is such a case—clear cut, simple in its details, with each step clearly indicated and determined by what has gone before, limning each of these steps vividly as

typical of those which are continually recurring in the annals of scientific achievement. A new discovery is made—hypotheses are set up for its explanation; further data are obtained, the hypotheses tested and either abandoned or modified by later workers; the work of these is in turn attacked and either rejected, modified as to claims, or approved. This cycle of events may be repeated several times. In the case of the cosmic ray story, the work is limited to a period of 25 years, in contrast to the much longer period which is often common. Probably because of this shortness of elapsed time, the steps of the scientific method are more clearly indicated than in most scientific chronicles. What is more, it is a fascinating story of scientific achievement, enacted on mountain tops, on the shores of snow-fed lakes, amidst the scurrying clouds—one that appeals to any high school group.

And now finally, "When shall we introduce it?" Because of its role in rounding out some of the concepts of the course, and of the difficulties of the subject, the story of the cosmic ray belongs, almost certainly, at the end of the year's work, presumably in connection with the study of radioactivity—possibly as a individual student's report, possibly as general class reference reading, even possibly as a story told by the teacher. Let us hope, however, that it will not be accorded the treatment so often reserved for these final topics—a hurried skimming in an effort to "get it in,"—or possibly complete omission. As has been indicated, the cosmic ray story furnishes intellectual stimuli and experiences that will serve admirably to round out and enrich the energy concept, and to furnish the student a real appreciation of the open-mindedness and painstaking care characteristic of a disciple of the scientific method. As such, it is worthy of a real place in any physics course.

Note: The Science News-Letter for Feb. 1, 1930, carries the interesting report that Kolhorster and Bothe of Germany have experimental evidence for the belief that the cosmic rays are really high-velocity particles like beta rays, or possibly like alpha particles.

"The possibility that cosmic rays may consist of moving particles instead of mere waves is admitted to have radical implications by the two experimenters. To carry such particles through the atmosphere would require a starting velocity imparted by a potential of at least a billion volts."

Dr. Curtis, of the Bureau of Standards, using a different method than the two Germans employed, has obtained results which "lend some support to the opinion of his German colleagues, but he is not yet satisfied that either the German work or his own constitutes full and conclusive proof."

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HIGH MOUNTAINS OF EASTERN UNITED STATES.

Accurate level lines have now been run by the Geological Survey, Department of the Interior, to six of the high peaks in the eastern part of the United States. Mount Mitchell, in North Carolina, which is probably the highest point in the United States east of the Mississippi River, is 6,684 feet above mean sea level.

Three peaks in the proposed Great Smoky Mountains National Park are Clingmans Dome, on the North Carolina-Tennessee State line, which has an elevation of 6,642 feet; Mount Guyot, also on the North Carolina-Tennessee line, 6,621 feet; and Le Conte (Myrtle Top), in Tennessee, 6,593 feet. Mount Washington, in New Hampshire, is 6,288 feet above mean sea level, and Mount Katahdin, in Maine, 5,267 feet.

The highest known point in the United States, exclusive of Alaska, is the summit of Mount Whitney, in California, which is 14,496 feet above sea level, and the lowest known dry land in the United States is in Death Valley, also in California, which is 276 feet below sea level.

THE MATHEMATICAL ASSOCIATION OF AMERICA, INC.

Dr. W. D. Cairns, Secretary-Treasurer of the Association contributed the following items: Professors E. T. Bell and W. C. Granstein were re-elected Vice-Presidents and Professors A. A. Bennett, A. F. Finkel, W. L. Hart and D. N. Lehmer were elected Trustees for a term of three years. The Chauvenet Prize of one hundred dollars was awarded to Professor T. H. Hildebrandt of the University of Michigan for his paper on "The Borel Theorem and Its Generalizations" in the *Bulletin of the American Mathematical Society* for 1926.

UTILIZING THE NATURAL INTERESTS OF PUPILS IN TEACHING BIOLOGY, PART III.

By O. D. Frank,

School of Education, The University of Chicago.

National Apple Week

To Capt. James Handly of Quincy, Illinois, belongs the honor of founding National Apple Day. More than twenty years ago, he conceived the idea that the King of Fruits, the American Apple, should be better and more widely known and to this end he suggested that a day be set aside each year for the celebration of National Apple Day. His suggestion was so favorably received that it was later thought best to devote a week to the celebration.

Beginning on Hallowe'en each year, cities, schools, and other organizations devote a week in displaying and studying the apple. The following outline will suggest ways of carrying on the celebration in schools:

1. Early in October science teachers should suggest the celebration to their classes.

2. Collect varieties of apples from orchards, the local markets, and from the various apple producing sections of the country.

3. Secure literature from the U. S. Dept. of Agriculture and from state bureaus of agriculture and horticulture.

4. Obtain posters, buttons, and other materials from National Apple Week Association, Rochester, New York.

5. Have pupils prepare slogans, posters, placards, songs, poems and plays pertaining to apples.

6. Co-operate with the Art and Domestic Science Departments.

7. Use glass cases and tables for displaying apples and apple products.

8. Pupils are always glad to supply jelly, sauce, pies, tarts, apple butter, cider, vinegar, and the many other apple products.

9. Grocerymen will lend samples of the apple products handeled in their stores.

10. Permit each room in the school to have an apple display. Offer a prize of a basket or box of apples for the most original and complete display. (The prize can be donated to an orphan's home, children's ward in some hospital or to some needy family. This, also, is a happy way to dispose of the apples and apple products at the close of the celebration.)

11. See to it that each teacher and every one connected with the school, including the janitors, is presented with a rosy or golden luscious apple.

12. Send invitations to parents, *grandparents*, and others to visit the display.

13. Some suggestions for displaying apples and apple products.

a. Secure as many varieties of apples as possible and place one of each variety on a large table. Label each apple carefully.

b. On another table arrange plates of apples (four apples, three below and one at the top) as follows:

(1) The largest apples, (2) smallest, (3) sweetest, (4) streakedest, (5) sourest, (6) reddest, (7) yellowest, (8) greenest, (9) best looking, (10) best for cooking, (11) best keeping, (12) best for shipping, (13) juciest, (14) mellowest, (15) most fragrant, (16) best for cider, (17) for sauce, (18) for baking, etc.

c. On still another table show variations in apples, i. e. largest to smallest of a given variety, various colors in a given variety.

d. An "apple hospital" in which diseased apples are displayed adds much to the celebration. Information telling how these diseases are prevented or cured may be placed on this table.

e. The "joker" or "clown" table draws many visitors. On this table the bright eyed "Irish Pippin" (a large potato), the "Spanish Wine Sap" (a large onion), "love apple" (tomato), the "Three Golden Apples of Hesperides" (three small pumpkins), "Italian crabs" (garlic), and many other original "apples" may be displayed. (Perhaps some ingenious boy can prepare a clay model of "Adam's Apple" for this joyous, joker jumble.)

14. The outline that follows has been used very successfully in the study of the apple:

An Outline for the Study of the Apple.

I. Origin of the apple.
II. Distribution of apples.
III. The apple orchard:
  1. Commercial value:
     a. Home consumption.
     b. Sale of fruit.
     c. Nesting place for birds.
     d. Relation to bee-keeping.
     e. Wood and bark uses
  2. Beauty and comfort.
  3. Diseases, insect pests, and other enemies and their control.
  4. Improvement of the apple tree.
IV. The apple as a food:
  1. Chemical properties.
  2. Relation of apples to health.
  3. Refrigeration of apples and other methods of storage.
  4. Canning and preserving.
  5. Other apple products.
V. The apple in Song, Games and Story:
  Captain Handly's Apple Song.

Planting the Apple Tree, by Wm. Cullen Bryant.
Story of William Tell.
Johnny Appleseed.
Apples Ripe for Eating, and Apple Pie and Cheese, by Edgar Guest.
Apple of Hesperides, by Nathaniel Hawthorne.

VI. Suggestions for the Celebration of Apple Week.

VII. Other fruits that bear the name of "Apple."

VIII. A study of the apple tree:

1. Roots.
2. Trunk.
3. Buds.
4. Blossoms.
5. Leaves.
6. Bark.

IX. A study of a single fruit:

A. The apple as a whole:

1. Common name.
2. Where produced.
3. Color.
4. Size.
5. Shape.
6. Odor.
7. Weight.
8. Stem end.
9. Blossom end.
10. Cost.

B. Parts of apple:

1. Stem: (a) size; (b) shape; (c) color; (d) strength.
2. Skin: (a) color; (b) markings; (c) thick or thin; (d) texture; (e) tough or tender; (f) sweet or sour.
3. Flesh or pulp:
(a) color: (b) texture; (c) mellow or firm; (d) juicy or mealy; (e) sweet or sour; (f) tough or tender; (g) color on exposure to air.
4. Core: (a) size; (b) shape; (c) divisions; (d) texture; (e) arrangement of seeds; (f) attachment of seeds.

X. Drawings (Label all drawings carefully):

1. Entire apple—natural colors.
2. Cross-section.
3. Longitudinal section.
4. A single seed.

XI. Give the uses of the skin, color, size, shape, odor, stem, core and flower to the apple.

XII. Tell some of the good points of the apple you are studying.

The interest and enthusiasm aroused through the apple day celebration does much to popularize the study of science, and it serves to fix in the minds of boys and girls that the apple is a healthful, luscious, beautiful, wholesome, delightful fruit that should be eaten every day.

Orange Study

When we eat together, we come to know each other better. The following device gives opportunity to study a most delicious fruit and gives the privilege of sampling the specimens. While the following outline is not complete, it is suggestive as to how the study may be carried on:

Materials needed: Florida and California oranges (approximately the same price per dozen), knives, paper plates, napkins, a large pan of water, candles, matches, rulers, string.

Procedure: 1. Note color, size, shape, markings, texture of skin, blossom end and stem end of the two oranges and record the facts on your mimeographed outline.

2. Place the two oranges in the pan of water. Which is the heavier?

3. Measure polar and equatorial circumferences of the two

oranges with the string. Measure these on the ruler and record your results. (P. C.+E.C.÷2= size of orange.)

4. Peel the oranges, being careful not to injure the flesh. Study the skins and record facts.

5. Light a candle and squeeze the oil from pieces of each of the two skins into the flame. Which skin shows the greater amount of oil?

6. Separate the sections of the flesh of the two oranges. Record the number of sections in each orange.

7. Study the flesh of each orange and record facts.

8. Remove the seeds, observe them carefully, and record your observations.

Record Sheet

Florida Orange.		California Orange.
	Comparative size	
	Shape	
	Weight	
	Color	
	Blossom end	
	Stem end	
	Skin	
	General color	
	Thickness	
	Texture	
	Oil content	
	Taste	
	Odor	
	Feel	
	Flesh	
	Color	
	Number of sections	
	Texture	
	Flavor	
	Juice contents	
	Total number of seeds	
	Number of perfect seeds	
	Cost of orange	

A large orange may be offered as a prize to any pupil who can suggest an additional item for the outline.

A Collection of Collections

Boys and girls are natural collectors. If you doubt the correctness of the above statement, examine the contents of boys' pockets or the overflowing pocket books that are carried by girls.

Inquiry will reveal that most boys and girls have various kinds of collections stored away at home. These can be brought to school and displayed on a table or in a large case. These collections never fail to create interest in Nature-Study and many of them are of such nature as to form a nucleus for a school museum.

Scientific arrangement and careful labeling add much to

the value and effectiveness of a collection of collections.

Kodak Pictures to Show How Plants and Animals Help and Hinder Each Other

No plant or animal lives unto itself. Each living thing is helped and hindered by its neighbors.

Kodak pictures showing the following make a most valuable and interesting collection:

How plants help plants
  Examples: Shade-loving plants.
  Vines supported by old snags.
How plants hinder plants.
  Examples: Dodder on clover.
  Grape vines choking a tree.
How plants help animals.
  Examples: Cattle in a pasture.
  Bird's nest in a tree.
How plants hinder animals.
  Examples: Boy with a sand bur in his heel.
  Weeds in a pasture.
How animals help animals.
  Examples: Boy on a pony's back.
  Old mother hen and chickens.
How animals hinder animals.
  Examples: Cat watching bird.
  Dog watching a treed cat.
How animals help plants.
  Examples: Bumble bee on a clover blossom.
  Gardener cultivating plants.
How animals hinder plants.
  Examples: Automobile filled with wild flowers.
  Apple trees gnawed by rabbits.

"Shooting" with a kodak is fascinating sport and field trips outlined on the basis of the eight "Hows" given above always "hit the spot." I have found no more interesting way of creating genuine enthusiasm for the big wonderful out-of-doors on the part of boys and girls than the plan I have just outlined. It not only shows the close relationship existing among living things, but it reveals as well some of the many problems that every living thing must solve in order to live.

Leaf and Flower Blue Prints

An interesting way to become acquainted with leaves, ferns, flowers and mosses is to make blue prints of them.

Blue print paper can be secured from paper supply houses. Regular printing frames used by photographers are ideal for printing on blue print paper but a pane of glass and a heavy piece of cardboard may be used quite as well.

The best prints are secured when fresh specimens are used. Place the specimen on the pane of glass or on the glass in the

printing frames. Place a sheet of proper sized blue print paper over the specimen with the sensitive side of the blue print paper in contact with your specimen. Lay a rather stiff cardboard or a thin wooden board over the blue print paper and hold it firmly as you expose your specimen to sunlight. Through trial and error you will find the proper length of exposure. The print is developed by dipping it in water. The prints will not curl if they are allowed to dry on blotting paper or other paper having a rough surface.

Blue prints of flowers tinted with water colors give them a realistic appearance.

Student Specialists

Even mediocre students rise to the occasion when they are made "specialists" on a given topic. To illustrate, John brought a beautiful Luna moth to class. He was made a "specialist" on moths and butterflies. In a short time John was able to answer most of the questions concerning his specialty. He gave a most interesting report on moths and butterflies, and the whole class became interested in moths and butterflies, through John's enthusiasm and through the questions they asked him.

Edward brought a bird house for the teacher's inspection. He became a bird house "specialist" and more than fifty bird houses were built under his direction. Boys who own bird houses don't throw stones at birds or shoot at them. "My" birds are protected.

Little Mary brought a pretty pebble to school. Through her efforts as "Rock and mineral specialist" a splendid collection was added to the school museum.

The "specialist" idea works well in teaching nature study.

Nature Poem Booklets

Many beautiful poems have been written about nature. Birds, trees, flowers, animals, the seasons, heavenly bodies, winding streams, shady dells, wind, rain, snow, butterflies, bees—all of these have always furnished the poet with themes and dreams for beautiful expression.

It is good fun to collect nature poems and arrange them in attractive booklets. True education includes the head and the heart and the hand. This little enterprise gives all three H's a means of expression.

Exchanging Collections

Purposefulness gives joy to the doing. Last year a 4B class

in a little school at the edge of the Sand Dunes made a collection of the interesting plants that are found growing in this region. Letters were sent to a similar grade in a Florida school near the ocean beach suggesting that "we exchange collections." As a result beautiful shells were sent in exchange for the interesting plant collections.

THE PROPERTIES OF RELATIONSHIPS IN ELEMENTARY MATHEMATICS.

By J. S. Georges,

The University High School, Chicago.

In a recent study[1] an attempt was made to determine the nature of reading difficulties encountered in mathematics. The number of reading difficulties caused by a lack of understanding of the nature of mathematical relationship between the elements in a statement comprises eleven per cent of the total number of cases reported. When the ratio is interpreted in the light of the small number of relationships studied the findings are quite significant.

An important observation in the study of this type of reading difficulties reveals the fact that the symmetric property of certain mathematical relationships such as "is equal to," "is complement of," offer both difficulties of expression and of interpretation. It is quite obvious that the statements "a equals b," and "a and b are equal" mean the same thing, but the student often finds it difficult to put the second statement in the form of the first. The same thing is true of the reflexive and the transitive properties of relationships.

Believing that a clear understanding of the nature of a mathematical relationship has considerable bearing upon its proper study, that is its symbolic expression and interpretation, this paper presents a brief resume of the properties of a few of the many relationships studied in elementary mathematics.

Relationships in mathematics may be classified according to their properties as follows: (1) reflexive relations, (2) symmetric relations, and (3) transitive relations.

A given relationship between any two elements or entities a and b is reflexive when upon making b identical with a the relation still holds. For example, the relation of equality is reflexive, for $a = a$; while the relation "is greater than" is not reflexive, for a is not greater than a.

[1] Georges, J. S., "The Nature of Difficulties Encountered in Reading Mathematics," The School Review, XXXVII, March, 1929, 217-226.

A given relationship between any two elements or entities a and b is symmetric if the relation is conversely true, that is if a is related to b in any manner then b is related to a in the same manner. Thus the relation "is equal to" is symmetric, for a is equal to b implies that b is equal to a; while the relation "is bisector of" is not symmetric, for a is bisector of b does not imply that b is bisector of a.

A given relationship between any three elements or entities a, b, and c is transitive if it is true that the relation between a and b, and the same relation between b and c together imply that the same relation holds between a and c. Thus the relation "is equal to" is transitive, for $a = b$, and $b = c$, together imply that $a = c$; but the relation "is perpendicular to" is not transitive, for a is perpendicular to b, and b is perpendicular to c do not together imply that a is perpendicular to c; in fact a is parallel to c.

Table I presents a classification of some of the most common relationships in elementary mathematics. The sign (+) indicates that the relationship has the property at the head of the column, while the sign (−) means the relationship does not have that property.

TABLE I—PROPERTIES OF MATHEMATICAL RELATIONSHIPS.

Relation	Reflexive	Symmetric	Transitive
1. Equality, is equal to	+	+	+
2. Inequality, is greater than	−	−	+
3. Inequality, is less than	−	−	+
4. Similarity, is similar to	+	+	+
5. Congruence, is congruent to	+	+	+
6. Equivalence, is equivalent to	+	+	+
7. Parallelism, is parallel to	+	+	+
8. Perpendicularity, is perpendicular to	−	+	−
9. Bisection, is bisector of	−	−	−
10. Complementary, is complement of	−	+	−
11. Supplementary, is supplement of	−	+	−
12. Factor, is factor of	+	−	+
13. Multiple, is multiple of	+	−	+

The reader might find it interesting to construct a similar table for such relations as concurrence, collinear, coplanar, concentric, prime factor, exponent, logarithm, function, tangent, asymptote, commensurable, etc.

Tests may be constructed based upon these three properties to reveal understanding of mathematical relationships. Such a test, rather simple, is presented below.

In each blank in the following statements insert the word or words which make the statement true:

A. a, b, and c any three numbers.

1. If $a=b$, and $b>c$, then a..................c.

2. If $a<b$, and $b=c$, then a..................c.
3. If $a>b$, then b..................a.
4. If $a<b$, and $b<c$, then a..................c.
5. If a is a factor of b, and $b=c$, then a..................c.
6. If a is a multiple of b, and b is a factor of c, then a..................c.
7. If a is a square of b, and b is a cube of c, then a..................c.
8. If a is a square of b, and b is a square root of c, then a..................c.

B. l, m, and n any three straight lines.

9. If l is parallel to m, and m is perpendicular to n, then l..................n.
10. If l is perpendicular to m, and m is perpendicular to n, then l..................n.
11. If $l+m>n$, and $l+n>m$, then $m+n$..................l.

C. x, y, and z any three angles.

12. If x is supplement of y, and y is equal to z, then x..................z.
13. If x is complement of y, and y is complement of z, then x..................z.
14. If x is equal to y, and y is complement of z, then x..................z.

D. P, Q, and R any three plane figures.

15. If P is similar to Q, and Q is congruent to R, then P..................R.
16. If P is congruent to Q, and Q is equivalent to R, then P..................R.
17. If P is similar to Q, and Q is equivalent to R, then P..................R.

INDUSTRIAL GEOGRAPHY.

By Bertha Willis,

Iowa City High School, Iowa City, Iowa.

Geography is a subject of intense human interest as it intimately affects the life of every individual and is, also, of great cultural value. It should hold a prominent place in the high school curriculum, if not placed on the list of required subjects. Too often the class is composed of those unhappy individuals who have failed in the first half of a year course and must then take up some half year course at the end of the first semester. It is very difficult to keep such a class interested. While the subject presents a great variety of interests, it just as readily lends itself to monotony. I remember my course in high school geography with a feeling of great weariness, induced by a long series of map drawing and compilation of dry facts.

The following are a few of the devices I have used to arouse the interest of the class. The work is organized into units and the exercises accompany the units. The units are not arranged in the order taken up.

Unit I. Causes and Effects of Industrial Geography.

Aims—to create a personal interest and to determine how man is engaged in satisfying human wants.

Study 1. Occupations.

Exercises:

a. Make a list of commodities used during the last 24 hours.
b. Group the 30 occupations given into six groups according to their similarity and name each group. Be prepared to defend your grouping in class.

c. Using the city directory, make a list of the occupations of the first 100 persons named under the letter of the alphabet assigned you. Group these occupations into the six classes worked out in exercise b. Draw a graph, to scale, to show the percentage of each group. Draw a second graph using the total number of occupations grouped by the class.

Study 2. The Relation of Topography to Industries. (A study of local conditions.)

Problems:

a. Why is agriculture the leading industry in this vicinity?
b. Why does Iowa produce great amounts of wheat, the principal cereal crop of the world's commerce, and of corn, the largest cereal crop of this or any country?

Exercises:

a. Relief Features of Iowa. Study the contour map of this region issued by the government. The features shown by this map are typical of the state as a whole. Note the scale of map, the contour interval, the regularity of the lines and describe the relief features. Note the effect of relief on location of roads, railroads and settlements. What would you infer to be the leading industry?
b. Climatic Conditions. From data given construct graphs showing the seasonal range of temperature and rainfall. Study the weather maps for seven consecutive days and determine the direction of movement of the high and low pressure areas across Iowa and the moisture bearing winds.
c. Soils. Study specimens of sand, loam, clay as to composition and capillarity.
d. Compare your results with conditions given in text as favorable to growth of wheat and corn.

Study 3. Improvement of Wheat and Corn by Man.

Exercises:

a. Report of the following methods of plant breeding:
   1. Selection—
      1′ Pine line selection.
      2′ Mass selection.
   2. Cross-breeding.
b. Study Mendel's Laws of Heredity.
c. Work out the Law of Chance by tossing two pennies up one hundred times, keeping record of the number of times each of the three possible combinations occur. Draw a graph to show the result and also one to show the total result for class.
d. Using white and red kernels of corn arrange them in order to illustrate Mendel's laws of heredity to the fourth generation. Draw a diagram to show the result of crossing a tall and dwarf variety of wheat. Tallness being dominant over dwarfness, carry out to the fourth generation.

Study 4. Enemies of Wheat and Corn.

Exercises:

a. Look up in the government bulletins the "Life History of the Wheat Rust." Construct a cycle to illustrate this. (Note: Secure from the state agricultural college a film of the history of the rust and show to class).
b. Report on the damage done by the corn borer and methods of control.

Study 5. Wheat and Corn Regions of the World.

Exercises:

a. On an outline map of the world locate the chief wheat and corn producing regions.
b. Indicate the countries which are important exporters and importers of these cereals. Why does corn play such an important part in the world's commerce?

Study 6. Cereal Crops Other than Wheat and Corn.

Exercises:

a. Make a list of other cereal crops raised in Iowa. Compare their optimum climatic conditions with those of wheat and corn.
b. Locate the areas of production of these cereals on the outline map drawn to show wheat and corn areas.

Study 7. Industries' Relation to Agriculture.

Make a list of industries related to agriculture and explain relationship.

UNIT II. COMMUNICATION AND TRANSPORTATION.

Study 1. Communication.

Exercises:

a. Primitive means of Communication, by messengers. Describe the experiences of one of the following persons: a Greek runner carrying the news of the invasion of Thrace by Darius, from Athens to Sparta; Paul Revere on his ride from Lexington to Concord; Kit Carson on his journey from California to Washington.
b. Modern Means of Communication. Give a report on one of the following topics: use of signal fires; the history of the mail service in America from 1676 to 1928 (see geography by James E. Chamberlain); the telegraph; telephone; sub-marine cable; the radio as a means of advertising. By means of the map showing principal highways of communication, locate the chief cable stations and trace a cablegram around the word

Study 2. Transportation.

Exercises:

a. By means of railroad guides locate on an outline map of North America the four great trunk lines of North America.
b. Route a car load of goods from Boston to San Francisco, naming the chief cities enroute.
c. Describe the experiences of a leader of a caravan across the Sahara from Kano to Tripoli. Name articles of commerce secured in Kano for there is a great demand in New York. (Read "The Caravan Trade of the Sahara" by Genivera Loft in the Journal of Geography, volume 15, page 221, for March, 1917).
d. Study the pilot charts of the Atlantic and Pacific for both winter and summer. (These can be secured on application from the U. S. government.) Study the ocean currents, the prevailing winds and the paths of icebergs. Work out the summer and winter routes of the high and low powered steamers and of sailing vessels.
e. Describe your experiences aboard a tramp steamer which leaves San Francisco and enters five foreign ports before returning. Tell what cargo is carried from port to port and why.

UNIT III. MANUFACTURING.

Exercises:

a. Visit a manufacturing establishment and give report.
b. You each have inherited a large sum of money on condition that you invest it in some manufacturing industry for which you think there is a demand. Choose a suitable location. Be prepared to defend your choice of industry and site before the class.
c. The girls in the class are to write out the autobiography of a silk dress from the time the silk worm is hatched in Japan until the dress is worn to a high school party. Each boy write the auto-biography of a Sunday edition of a newspaper.

Match tests are used frequently. In manufacturing, for instance, each student is given a mimeographed list of manufacturing cities, industry for which each is noted and factors which

have determined the location of the industries. These lists are arranged irregularly in three columns and are to be correctly arranged.

Limited True and False Tests are also used. Mimeographed copies of true and false statements are given out and pupil must tell why the statement is true or false. Such a test takes much longer to make out and look over than the simple true or false but involves reasoning on the part of pupil and not guess work.

PRIZE MONEY FOR TEACHERS.

The American Forests and Forest Life magazine published by The American Forestry Association, announces a contest designed to aid teachers to enrich their pupils' knowledge for trees, forests, and related outdoor fields through supplementary reading and the use of visual material in the schools.

The instructive articles and illustrations which appear in every issue of the magazine are used in many schools, and with the aid of the "Science Education Page" conducted by Ellis C. Persing, School of Education, Western Reserve University, have proved as of great value in connection with regular textbook assignments.

The Contest.

For the best suggestion embodying a detailed lesson plan and outlining how American Forests and Forest Life can best be used in the schools, the following cash prizes are awarded:

First prize	$50
Second prize	$25
Third prize	$10

For the next five best suggestions, yearly subscriptions to American Forests and Forest Life will be awarded.

You do not have to be a subscriber to the magazine to participate in the contest. If your school is not receiving the magazine, procure a copy from your local city or town library, or send twenty-five cents in stamps for a sample copy to The American Forestry Association, Washington, D. C. Better still, enroll for a special schools subscription at one-half the regular yearly rates.

Rules of the Contest.

The contest is open to all teachers, from grades one to twelve.

Manuscripts should be limited to one thousand words or less, but there is no limit on the number of plans which a teacher may submit.

Write on one side of the paper only, and in the upper left hand corner of the first page give your name, grade you teach, name of department, name and location of your school.

Manuscripts will not be returned unless accompanied by the necessary return postage.

The contest closes on June 1, and manuscripts mailed after that date will not be considered. All manuscripts should be addressed to School Contest Editor, American Forests and Forest Life, 1523 L Street, N. W., Washington, D. C.

SUPERSTITION AND SCIENCE TEACHING.[1]

By J. O. Frank,

State Teachers College, Oshkosh, Wis.

Three rather well defined criticisms of High School Science teaching seem to be voiced by critics more often than any others. These may be briefly stated as follows:

(a) The rather isolated bodies of scientific knowledge obtained in one, two or three units of high school science cover no complete or unified field. Certain fields of science are "taboo" and have not been touched at all. Such units as have been treated do not dovetail; they do not develop a useful understanding of the broad general principles of science. There are great gaps or holes—connecting fields which have not been touched. The high school has given no summarizing course to weld these units into a connected whole. The student still thinks in terms of the units of science rather than in science as a whole. He thinks in terms of isolated experiences—rather than broad general principles. He often finishes without a clear cut understanding of many of the most fundamental conceptions of science.

(b) Newspaper and magazine science with all its half truths and glaring inaccuracies is a potent factor in bringing to the young American student a mass of misinformation with which high school science seems unable to cope.

(c) There is still a great body of traditions, superstitions, and half truths, which is the heritage of every child who enters the public schools or has social contacts with the American public. Old ladies' tales, belief in luck, weather signs, fortelling future events, charms, magic cures for disease, and the like are quite common, and undoubtedly influence the activities of everyday life. The things the child learns in the high school, the common beliefs of the children of everyday acquaintance and the science of the newspaper, do not agree and the average child becomes suspicious and feels that little is certainly known about science or else there is a general conspiracy to keep the truth from him.

In an attempt to determine to what extent these criticisms were justified a series of studies was begun at Oshkosh State Teachers College in 1924. One of these included an investigation of common superstitions of the Fox River Valley of Wisconsin. Before actually beginning the investigation all available

[1]From a paper read before the All Science Section of the Wisconsin State Teachers Association at Milwaukee, Nov. 8, 1929.

evidence of the presence of these superstitions was gathered and classified. This evidence was found to be of the following types:

(a) Statements of numerous authors—including historians, educators, and sociologists—declaring the presence of these superstitions.

(b) Common sayings and traditions as reported by residents of the region under investigation.

(c) The demand for cheap almanacs, dream books, books on magic, and the like as reported by druggists, book sellers, and others and as indicated by the presence of these books and pamphlets in homes of the region.

(d) Newspaper articles referring to weather signs, dreams, lucky numbers, and the like; and feature articles of this type in the supplements of Sunday Editions of the more important newspapers sold in this region.

The Problem

After gathering existing evidence of the presence of numerous superstitions in the regions under investigation, it was decided to attempt the following:

1. To find out just what are the most common superstitions of the Fox River Valley.

2. To determine to what extent these superstitions affect everyday life.

3. If these superstitions were found to be numerous and of considerable importance as shown by their influence on everyday life—to determine how our high school science teaching might help eliminate their influence.

What Was Done

Beginning in 1924-25 students in seven Biology classes were asked to aid in listing the superstitions of the Fox River Valley, since nearly all of these students were residents of this region or of localities on its borders. Students from five classes under J. O. Frank and two classes under H. W. Talbot (a total of 518 students) took part in the work. Each student made a list of all the common superstitions of his home community. He submitted this list to at least three persons of his community with a request for any additions which these persons might be able to make. So far as possible the students were requested to select persons of different types and it was suggested that one farmer, one business man, and one middle aged woman be asked to con-

tribute to the list. From the 518 students, 488 papers were received and studied.

The total number of different superstitions reported was 1224, not counting about 50 misconceptions of scientific principles which really have much the same detrimental effect as true superstitions. The prevalence of two types of false ideas had not been foreseen, so no attempt was made to have the students discriminate between them, but in tabulating the beliefs reported such beliefs as "The sun draws water into the clouds" and "The ashes of a sponge will cure sore throat" were excluded.

A card was made for each superstition reported and as the papers were read the frequency of each was recorded. Throughout this process of tabulating it was necessary to disregard the actual wording and to look for the central idea of the beliefs reported. The various beliefs and the number of times each was reported is given in the following list. (Only those occurring more than 20 times in the 488 papers are given.)

THE MOST COMMON SUPERSTITIONS OF THE FOX RIVER VALLEY OF WISCONSIN

Subject	*Number of times reported*
A black cat brings bad luck	484
Finding a horseshoe brings good luck	442
Breaking a mirror brings bad luck	411
Friday the 13th is a very unlucky day	391
Thirteen people at a table—death or bad luck	388
Walking under a ladder brings bad luck	327
Sing before breakfast—cry before night	281
Four leafed clover brings good luck	280
A rabbit's foot brings good luck	279
Dog howls at night—a death follows	274
Groundhog sees his shadow on groundhog day—6 weeks of bad weather	222
Two persons walk on opposite sides of an object—bad luck	202
Drop silver at table—company coming	200
Warts removed by various charms	184
Clothing on wrong—bad luck to change	182
Amber beads will prevent goiter	165
Ears ringing—being talked about	153
Toads cause warts	135
Itching of palm of hand—money	133
Kill a toad—brings rain	123
Wishbone of chicken—wishes	122
Seven—good luck	118
Pick up a pin—good luck	112
Open umbrella in house—bad luck	111
Falling star (meteor)—a death follows	96
Ring around the moon—storm follows	96
Kill a cat—bad luck	97
Rain before seven—quiet before eleven	94
Sun sets red—good weather	94

See new moon over right shoulder—good luck	91
Three smokes lighted with one match—bad luck	90
Buckeye or chestnut carried in pocket—prevents rheumatism	90
Horse hair soaked in water—becomes a worm	88
Wish on first star—wish comes true	82
Get up on wrong side of bed—bad luck	79
Fortunes can be told with cards—(tea leaves, etc.)	75
Dogs eat grass—rain	74
Dream on wedding cake—dream comes true	72
See new moon over left shoulder—bad luck	71
Find hairpin—good luck	68
Pointed or edged gift—breaks friendship	63
Opal, unless birthstone—bad luck	61
Pierce ears—cures weak eyes	60
Spill salt—cause quarrel	60
Drop dish towel—company coming	57
Wish on load of hay—wish comes true	56
Stub your toe—meet your beau	55
Return to house—sit down or bad luck	54
Catch bride's bouquet—next to marry	53
Nose itches—kiss a fool	51
Lucky (coins—stones)	50
Rain in a grave—another death in family	50
Count carriages at funeral—another death in family	49
Clip hair with new moon—health	48
Camphor bag around neck—prevents disease	48
Cut thick slice of bread—good step-mother	48
L mark on stones from sheep's head (fish)—good luck	48
Cat has nine lives	44
Go in one door and out the other—company coming	43
Star falls—say money—will find money if hunt	42
Find hairpin—will find new friend	42
Brag—knock on wood or bad luck	40
Angle worms rain from the sky	40
Take last piece of cake—will be an old maid	40
Death raps—predict death	40
Red sky in morning—predicts bad weather	40
Bury baby tooth—no animal gets it—better teeth	39
Dream of wedding—death	38
Wish ring on—wish comes true	38
Two look in mirror at same time—bad luck	38
Heavy fur on animal—long winter	38
Drop fork—man coming	38
Bird flies against window—death	38
Dry, thick husks on corn—predicts long winter	37
Dream of the dead—hear from the living	37
Eleven—unlucky number (or lucky number)	37
Pain in side—pick up stone—spit on it—put it back—cure	35
See white horse—brings luck	35
To itch excessively—means journey	33
Spit on fish bait—good luck	33
Kill spider—brings rain	33
Rain falls with bubbles on water—rain three days	33
Cat eats grass—rain	33
Swallow hair—will have worms	33
Rock empty chair—death	33
Ghosts—fairies—spirits	32
Five leafed clover—bad luck	31
Find a pin—leave it—bad luck	31
Rains first Sunday of month—rest will be rainy	30
Two talk at same time—make wish—will come true	30
Take more bread when you have some—someone coming hungry	30
Moon shines on face while asleep—makes insanity	30

Last rehearsal poor—play will be good	20
Three lamps in a row—marriage	20
Job started on Friday—never finished	20
Northern lights bright—bad weather	20
Put on left shoe first—good luck	20
Enter front door—leave back door—bad luck	20

The most common superstitious beliefs of the region studied are listed above. It is obvious that it would be impossible to give all the 1224 beliefs in this paper, though it is quite possible that some of the less common beliefs are just as important as those mentioned more frequently. In an attempt to classify the various beliefs on basis of the central idea represented the following results were obtained:

CLASSIFICATION

Subject	*Frequency*
Luck (102 bad—73 good)	175
Death	126
Weather	108
Omens	66
Wishes	52
Prevention of diseases	44
Insects or bugs	40
Snakes	31
Itching	31
Cows	31
Dogs	26
Cure of disease	20
Money	18
Heavenly bodies affect crops	16
Fortune telling	16
Finding lost objects	12
Gifts	11
Transformation	11
Cause of desease	11

CONCLUSION

In the foregoing report, the most common superstitions of the Fox River Valley of Wisconsin have been listed. In other papers to appear shortly the findings of the rest of the study will be given.

FREEDOM OF LEARNING.

"Believing, as I do, that the freedom of learning is the vital breath of democracy and progress, I trust that a recognition of its supreme importance will direct the hand of power and that our public schools and state universities may enjoy the priceless advantages of courses of instruction designed to promote the acquisition of all knowledge and may be placed under no restrictions to prevent it; and that our teachers may be encouraged to know and to teach the truth, the whole truth and nothing but the truth. This is the path of salvation of men and democracy."—Charles Evans Hughes, before the American Bar Association.

THE EVOLUTION OF PHYSICAL CONCEPTS.*

By E. H. Johnson,
Kenyon College, Gambier, Ohio.

It is quite generally recognized that a large part of present-day physical science is the product of a period well within the memory of people still living. Many of the ideas that determine our reactions to the world about us are of too recent an origin to have become generally coördinated with the philosophy we have inherited. Possibly this would have been equally true at any other time since the human story began, for growth always has resulted from the continual mental adaptation to the outer world, and, inasmuch as the inner world is something of a composite reflection of what is received from external things, it will change and broaden with every increase in our understanding of what actually is going on around us. It is impossible to trace this interest to its origins, but its course throughout the historic period towards a goal now dimly recognized, has been singularly direct. The complicated mechanism of the physical world has changed little if any, but as every new discovery has necessitated some revision of general concepts, any slowness in development has been in the human ability to see things as they are and to interpret the findings consistently.

In following the growth of physical concepts it is only proper to recognize the essential sincerity of the framers of each new theory. Whatever of progress has been made has resulted from the incorrect as well as the correct hypotheses. A charitable study of the status of physical science at any time shows conclusively that each step towards the use and control of natural phenomena has followed some extension of previous conceptions and, in turn, it has been limited in extent by the scope of the current theories. Theory and observation have gone hand in hand or waited one for the other. In many instances observation of the less evident phenomena of Nature has been retarded by the lack of a suitable directing theory, and although it may be true that the answers to many questions "are just beneath the surface of common things," it has become increasingly imperative that the search be guided by as intelligent a plan as all previous observations and coördinating hypotheses can afford.

This limitation is well illustrated by some of the ideas of matter current at the time when Greek philosophy was at its height.

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*Read before the Ohio Beta Chapter of the Phi Beta Kappa Society at Kenyon College, January 17, 1929.

Even centuries later, little physical data was obtainable by other than the unaided senses. For example, the Greeks would have found it equally impossible to conceive of the distances with which the telescope has made us familiar, or with the subatomic structure we are just beginning to discover. But even then, there were theories, however crude, that were destined to lead all later investigations in both fields. Only in recent years could it be seen that progress in either direction was to be made by means of the same agency.

Much of Greek speculation dealt with origins and first principles. It was not understood that the proper object of scientific investigation was to discover how natural phenomena are related rather than why they occur. The explanations of existing conditions were sought by means of philosophical structures that still command one's admiration. The man who conceived of a world made up of, say, the four elements, earth, water, air and fire, was wholly consistent considering the meagerness of his data. His mental difficulties in overstepping the bounds of actual knowledge were fully as great as are ours, and yet his theories of atoms pointed henceforth to the fields where modern investigation has found its richest rewards. He bequeathed to later ages a guiding concept leading to the time when methods should become available for checking its validity. In astronomy ancient observations remain a useful part of present-day records. It should not be forgotten that the Pythagoreans even arrived at the conclusion that our earth is only a minor part of a system having a central fire, although two thousand years had to pass before Copernicus could develop the heliocentric theory. He returned to the Pythagorean idea because the intervening centuries had produced ample evidence that no scheme differing from it fundamentally could be true.

In the meantime a wholly different conception of the mechanism of the solar system had found wide acceptance. Probably the geocentric theory was the older of the two, In the first place, it fitted the more evident phenomena; it was acceptable to the man in the street because it seemed natural. Moreover it was easily reconciled with the religious philosophies dominant in Western Europe until the Renaissance, by being essentially a homocentric theory. Long after the time of Copernicus there were many astronomers who regarded the Ptolemaic theory as the more logical. Thus, two age-old concepts struggled for a supremacy that could be determined only by the acquisition of

more data. We should remember that the gathering of this material was guided throughout by a wide knowledge of the implications on both sides. Our present acquaintance with the physical universe has been attained by a selective process.

The vitality of the Greek theories about the world is nowhere better shown than in those branches directly dependent upon geometry. In the early part of the Seventeenth Century we find Kepler still struggling against the old idea that the planetary system must have an arrangement conforming to the five regular solids of Euclid. His own account shows with what difficulty new ideas replace old ones. His years of effort with this problem and the extravagance with which he reveled over his new conception when at last he saw its simplicity, are well known. One cannot help wondering what he would have thought if he could have seen a twentieth century textbook in which his Laws of Planetary Motion are applied to electronic orbits. Surely such conceptions must be pretty faithful pictures of operations fundamental in Nature.

The age in which lived Kepler, Galileo and Newton had the advantage of the remarkable growth in geographical knowledge during the Fifteenth and Sixteenth Centuries. The discovery of new continents did more than furnish data for the cartographer. Magellan's expedition was not necessary to demonstrate the rotundity of the earth, for lunar eclipses had been interpreted correctly at a very early time, and more than two centuries before the beginning of the Christian Era Eratosthenes had determined the size of the globe with a clearness of insight and a degree of accuracy that mark his work as one of the supreme accomplishments of mankind.

The Seventeenth Century was so productive of new physical ideas that the Eighteenth was largely occupied in digesting them. Conspicuous were the advances made in mechanics. Galileo laid firm foundations. Kepler's laws, while faithfully descriptive, were of the integral type, ignoring causal relations. Newton, however, provided the modern physicist with his most useful tools by the introduction of the use of differential expressions. The impetus thus given mechanics reached an impressive climax in the Nebular Hypothesis of Kant and Laplace. At the same time, Newton's masterly treatment of the erroneous corpuscular theory of light left it dominant throughout the Eighteenth Century. Probably he knew as much about the possibilities of a

wave theory as did any of his contemporaries, but his conception of the nature of light was based on the state of knowledge at the time. The wave theory of Huygens was largely an hypothesis. Although Newton could not explain the absence of the enormous pressure that would result from the bombardment by his corpuscles, Huygens was equally at a loss to account for the phenomena of polarization and rectilinear propagation.

About a hundred years had to pass before it could be shown that a modified undulatory theory was more in accordance with the facts than one assuming a material emission. This battle of a century brought out the weak and strong points in both theories, and all later physics profited thereby. But the question is by no means settled, for as the result of recent discoveries, physicists today are less ready to insist on the undulatory nature of light than they were at any time during the Nineteenth Century.

One conspicuous exception to the materialism of the Eighteenth Century was the belief in a vital force that would forever limit experimentation in the organic world. It required the work of Wöhler in synthesizing urea in 1828 to show that organic processes are not unique but fundamentally the same as those found elsewhere.

The main features in the development of physical science between 1800 and 1900 are too well known to warrant much comment. The uncertain current of the underlying thought is not so generally appreciated. At the very beginning of the century the basis for a whole new philosophy was laid by Rumford. His observation of the unlimited amount of heat that could be obtained from friction alone should have dealt a deathblow to the doctrine that heat was a form of matter. The idea itself was not wholly new for the kinetic nature of heat had been suspected by Francis Bacon. However, Rumford's work lacked the quantitative aspects necessary to make it conclusive. He had demonstrated that heat had no weight, and he had concluded that it was merely a new form of the work done by the horse that turned the experimental mechanism. But such a concept was still so novel as to do violence to the judgments of many experienced investigators who clung to the ideas of the phlogiston theory. At best they could only admit that heat might be an "imponderable" form of matter. The argument that lasted during the next fifty years was carried from stage to stage by experiment finally terminating in the classical work of

Joule which demonstrated that Rumford was right. The heat of friction was from the work done, or better, it was a new form of the energy expended in doing the work.

The acceptance of this concept divided the universe between two great entities, matter and energy. The reactionary swing to the idea was so decided that the demonstration in our own times of an actual kinship between the two came as a great surprise. Undoubtedly the development of the science of thermodynamics from the investigations of Carnot in 1824 is destined to play a more permanent part in shaping physical philosophy because of its independence of many of the provisional hypotheses about the nature of heat that have been found useful elsewhere. It is of interest, however, to note that much of the terminology still used in discussing thermal phenomena is a heritage from the days of caloric.

Simultaneous with these investigations were those in the fields of electricity and magnetism. Thales had observed some of the fundamental phenomena nearly twenty-five hundred years earlier, but up to the time when Franklin facilitated electrical investigations with his single-fluid theory, little progress had been made. Here was another form of matter, an imponderable fluid. That it was a form of energy could not be suspected until after 1820 when Oersted demonstrated the interactions between electric currents and magnets. Whole groups of new concepts had to be acquired before the new agencies could be made human servants. Many of these sprang directly from the mind of Faraday. The subsequent work of Maxwell in developing the electromagnetic theory of light was largely a reshaping of Faraday's ideas in terms of mathematical expressions suitable for application to problems of wide variety. The possibilities of a new idea have rarely been shown better than in the chain of developments resulting in this field. The story is well known; its sequences and climax are suggested amply by a mere recital of the names of the four successive investigators, Faraday, Maxwell, Hertz and Marconi.

Thus we see that much of the evolution of physical ideas during the Nineteenth Century was a breaking away from the notion of imponderables, and replacing it with a generalized energy concept. This was facilitated immeasurably by the increased use of statistical methods and the theory of probability following the suggestions of Boltzmann. Energy was the century's contribution to the knowledge of the workings of the

universe, whether the term itself be retained or replaced by some other found to be more definitive of the entity involved.

To the layman the Nineteenth Century was notable for the conspicuous application of concepts unknown in the preceding centuries. Towards the end of the century the state of physical knowledge seemed so conclusive that by 1890 even the majority of physicists felt that most of the big discoveries had been made, and that future investigators would have to content themselves with refinements in measurement and to the determination of additional decimal places.

In the light of this opinion, it is interesting to recall that the next step did not depend on exact measurements, although keenness of observation was as essential as ever. In 1895 a new tool for investigation in what has been termed "ether physics" was found by Roentgen. The nature and later development of X-ray research need no telling. The phenomena discovered right and left during the next thirty years would have been quite inconceivable from Nineteenth Century viewpoints.

Shortly after Professor Roentgen's discovery a closely allied field was opened by the researches of Becquerel and the Curies. In the study of radioactivity the physicist found that not the least of the new problems raised was that of the readjustment of his own conceptions of energy and time. He had come to place considerable confidence in the theories of the conservation of matter and energy. Here they seemed to crumble. But it was found that there were processes in Nature involving transformations and periods of time hitherto unsuspected. With the proper rearrangement of ideas, the picture was clearer than before, although much extended and displaying relationships that altered the entire philosophical equipment of the physicist.

For some years it had been thought that possibly electricity might be "granular." The new post-Roentgen physics bristled with phenomena that could be explained only by the recognition of a close relation between electricity and matter. In their original form the Nineteenth Century ideas of conservation were no longer tenable. Even the permanence of the elements was found to be illusory. A Bishop Berkeley would have found rich opportunities for speculation and argument. There were also evidences of the existence of large stores of energy within the atom, and when it was demonstrated that electricity does have a discontinuous structure composed of units, or electrons which could be measured in terms hitherto applied only to matter,

the old distinction was nearly gone. But one new concept leads to another. This electron was found to have a variable mass depending on its velocity, while energy behaved as if endowed with inertia. In fact there was proof that matter and energy were interchangeable. The annihilation of even a small amount of matter seemed to be simultaneously the birth of an enormous amount of radiant energy. Einstein showed that the phenomena of gravitation that had so puzzled Newton could be more easily explained by combining the gravitational and inertial properties of matter and introducing the concept of curved space. Shades of Eighteenth and Nineteenth Century mechanics! Here was pabulum for philosophers indeed, and as we will see shortly these ideas have an important bearing on the interpretation of phenomena even in the farthest parts of the visible universe.

This does not mean that the electromagnetic theory is to be wholly discarded. The successes of the ether theory cannot be overlooked, for many of the data involved are matters of measurement, and it is still regarded by many as useful, although a repetition of the famous Michelson-Morley Experiment during the past year has failed to prove the existence of such a light-bearing medium by the certain detection of the slightest relative movement of the earth through it. At the same time, experimental work just as recent has indicated that a stream of electrons has many of the characteristics of a wave-train. Photo-electric phenomena in which electrons are ejected with enormous velocities from matter that is subjected to high frequency radiation, suggest a corpuscular rather than an undulatory transmission. It has been found that the energy of the emitted electrons is independent of the intensity of the incident radiation, but is determined by its frequency (ν), with a numerical factor of proportionality that seems to be a constant of Nature. This is Planck's universal constant of action, h. The energy absorbed seems to be in integral multiples of the product, $h\nu$. It is this unit that is termed the "quantum."

The reverse phenomenon in which monochromatic radiation apparently results when there is an alteration in an electron's energy, is likewise at odds with the classical doctrine. Here again Planck's constant appears, and we begin to appreciate the inadequacy of the old conceptions.

Naturally these new ideas have led to ingenious pictures of the mechanism of the atom itself. While none of these is regarded as final, they have been exceedingly useful. They have made

possible the removal of many very evident discrepancies in the arrangement and interpretation of the Periodic Table. An elaborate atomic and sub-atomic mechanics has introduced some drastic alterations in the gross mechanics of Newton. For example, the appearance of Planck's constant in expressions for certain kinds of periodic motion suggests a discontinuity that would have been abhorrent a few years ago.

At present there are several highly artificial methods for bridging these apparent gaps. That they are of the nature of expedients is granted, but already their partial successes have brought an assurance of underlying order in spite of the newly-discovered complexities. There is at present almost a feverish expectancy that at any time the entire situation may be clarified by a new unifying generalization that will rival those of Newton and Darwin.

Let us now examine for a moment the bearing of these new views on cosmical physics. Life as we know it is limited to such a narrow range of conditions that we are just beginning to get some idea of the possibilities in the universe outside of the earth. This has been forwarded largely by the laboratory discoveries in radiation and atomic structure.

In 1863 Huggins attached a spectroscope to a telescope and began the study of what for many years was regarded as the chemistry of the stars. At present a more approved terminology would designate it as a portion of an all-inclusive investigation of matter and radiation. For example, the idea that continuous spectra can be emitted only by solid or liquid radiators is now considered as less certain than that such radiating masses are not transparent like the planetary nebulae. Otherwise little is known of their structure. Many of them are what are termed full radiators, probably having complete molecules only in their outer layers, while a little deeper down the atoms have lost a part of their normal complement of electrons. In the central portions, at great distances from the surface exist only free electrons and completely stripped nuclei, behaving like a mixture of monatomic gases. The internal radiation pressures may be as high as two billion atmospheres, while the gas pressures there are probably twenty times larger. This means temperatures possibly in excess of thirty million degrees Centigrade. In a large star, the radiation pressure may equal that of the gas, and these together may constitute the forces that enable it to maintain its volume in spite of its own gravitational tendencies.

These high pressures necessitate very small mean free paths of the internal atoms, and limit the transport of energy by atomic agitation such as we observe in gases in the laboratory. Hence radiation must remain the principal agent for the transference of energy from the interior of the larger stellar masses. On these assumptions it has been shown by Jeans that a star probably adjusts its surface temperature and its radius in accordance with the rate at which its internal energy is being generated.

In general the condition of a given star seems to depend on its opacity to this internal radiation. Homogeniety is prevented by the high internal density which precludes convection. The outer elements are only the lighter ones, while deep within the glowing mass there may be elements far heavier than any known terrestrially. As the star grows older, the average atomic weight of its constituent elements decreases. Probably there is a perpetual evolutionary process similar to that observed taking place in a few of our heavier elements, the members of the radioactive series. That is, there is a disintegration amounting to a change from complex to simpler atoms. Such a process may constitute a source of stellar radiant energy, for here again we are forced to recognize the probability of electronic and nuclear collisions, resulting in the annihilation of matter, and the simultaneous liberation—creation, if you please—of vast quantities of energy. It is thought that the newly-discovered penetrating "cosmic" rays may have originated in such atomic transformations in far distant stars, and also that they indicate the continuous creation somewhere of the very elements with which we are familiar. Thus, while we are acquainted directly with only the lighter kinds of atoms and a small range of energy sources, we have proof on every side that Nature's primary process is radiation.

After all, our fundamental concepts are pictures of sets of operations. One of the oldest problems of science has been the reconciliation of new theories and ideas with those hallowed by long acceptance. At last we are beginning to see that through the infinite complexity of the universe there runs a marvelous simplicity, but one capable of disclosing new wonders and beauties as long as human interest shall endure.

"Bad men spring from bad things; hence let us correct the things."—*Victor Hugo.*

DO STUDENTS WHO STUDY CHEMISTRY IN HIGH SCHOOL ELECT THAT SUBJECT IN COLLEGE?

BY CLIFF R. OTTO and MABEL CLAIRE INLOW,

Central State Teachers College, Edmond, Okla.

A study of the transcripts of 906 degree graduates of a state teachers college was made in an endeavor to determine whether or not students who had studied high school chemistry showed a greater probability toward electing college chemistry than did those who entered college without high school chemistry.

The authors began this study with the idea that a student who has studied chemistry in high school is much more likely to elect chemistry to fulfill his college science requirements than is one who has not studied chemistry in his preparatory work.

The transcripts of 906 graduates were studied. Practically all of these graduates were people who have prepared themselves for teaching as they have done their college work in a teacher training institution. All of them have received their college degrees since 1920.

TABLE A.

Number of transcripts studied	906
Number who entered college with H. S. chemistry	99
Percent of total entering with H. S. chemistry	11
Number who entered college without H. S. chemistry	807
Percent of total who entered college without H. S. chemistry	89
Number who studied chemistry in H. S. and college	50
Percent of those who had H. S. chemistry who elected college chemistry	50
Number who studied chemistry in college only	349
Percent of those who did not have H. S. chemistry who elected college chemistry	43.2
Percent of those who did not have H. S. chemistry who did not elect college chemistry	56.7
Number who never studied chemistry at any time	458
Percent of total who never studied chemistry at any time	50.5

From a study of Table A it will be seen that 807 of the 906 students had received no training in chemistry during their preparatory courses. This is due partly to the fact that only about 12 per cent of the high schools of Oklahoma offer chemistry. Further, many high school students who have an opportunity to study chemistry do not choose that subject.

The outstanding feature of the investigation was the fact that the results did not show conclusively that students in this institution who have studied chemistry in high school are more likely to elect courses in college chemistry than those who have not received instruction in chemistry in high school. Only fifty percent of those entering with high school chemistry elected

to study the subject in college. Over forty-three percent of all graduates who had never received any instruction in chemistry in high school elected the subject to fulfill their college science requirements. The small difference of 7 percent may easily be accounted for by the fact that a better class of students may elect to study chemistry in high school.

Certainly one of the major objectives in high school chemistry teaching should be to interest the young student in chemistry. This is probably not being done when students who have never been in a class in high school chemistry elect college chemistry almost as readily as do those who have.

What happened to that other fifty percent who studied chemistry in high school and did not pursue the subject further during their four years in college? Did they try it out in high school and decide that they wanted no more of it? Were some of them kept out of chemistry courses on account of excessive requirements in their professional work in teacher training? Did they study just enough chemistry to learn that they had to work at it and take an easier route? These questions are important to the teacher of chemistry and to the individual who desires to see chemical interest and information extended to the general public.

However, we as chemistry teachers can have no quarrel with the student who tries out the subject of chemistry at some time in his school career and takes no more of it. It may be the fault of the teacher but in most cases the real reason lies with the student himself. But, we do believe that most students who graduate from a college or university should get well enough acquainted with the subject of chemistry to know whether or not they would care to pursue it further.

The place for missionary work as shown in this investigation is with the 50.5 per cent of graduates who have not entered any chemistry course either in high school or college. It may be said that most of them are going out to work as grade or elementary teachers and will have no need for a knowledge of chemistry. This idea is far from true. There are scores of ways in which grade school teachers can weave a knowledge of chemistry into their teaching to the mutual benefit of both their pupils and themselves. The number of teachers who are graduating from college without ever receiving any insight into the science of chemistry must be reduced.

The number in this institution who receive no training in

chemistry will probably not be far out of line with that in other institutions of similar rank and purpose.

Summary

It was found that 50 percent of the students who entered this state teachers college after having received high school training in chemistry elected the subject to fulfill their college science requirement. It was also found that 43.2 percent of those who had not studied any chemistry in high school elected to study college chemistry. These results do not indicate that high school chemistry teaching is having much effect toward inducing students to elect college chemistry. It was further shown that 50.5 percent of the 906 degree graduates have never entered any chemistry course.

WHO ORIGINATED THE SUGGESTION SYSTEM?

By W. F. Schaphorst, M. E.,

45 Academy St., Newark, N. J.

Nearly everybody has heard of the famous John H. Patterson, founder of the National Cash Register Company. But I dare say that few people are aware of the fact that entire credit is due Mr. Patterson for originating the modern "suggestion system." He developed a system for his own employes which was the forerunner of all suggestion systems today.

One of Mr. Patterson's workmen told him about 35 years ago—in 1894—that he had an idea which he believed was of value to the National Cash Register Company. Mr. Patterson said: "Why not make your suggestions in writing, if only to show your foreman you are capable of holding a better position?"

To this the man replied: "What's the use? If I did, the foreman would take all the credit."

Mr. Patterson saw the situation as viewed by the workman and that conversation resulted in a suggestion system which he immediately put into operation. His idea was that the system should benefit both the company and the employes.

The system "worked." It worked so well that nearly every institution of today, large and small, has a suggestion system patterned very much after that conceived by Mr. Patterson. Employes are invited to drop suggestions into boxes that are provided in several places about the plant. Every suggestion is considered, and those that are adopted are paid for.

It is usually found that the suggestion system is decidedly profitable. For example I have before me a report concerning one large company which considered over 12,000 suggestions in one year and adopted over 3,000 of them. The amount of money paid for each suggestion averaged nearly $13.00. It was estimated that each suggestion during one year effected an average saving of over $130.00. Based on the amount earned per suggestion it is easy to figure that the total earnings during that year alone amounted to about $400,000.

OTHER SIDES OF MATHEMATICAL STATEMENTS IN THE NEW EDITION OF THE BRITANNICA.

By G. A. Miller,

University of Illinois, Urbana, Ill.

Teachers of mathematics naturally prize very highly the mathematical articles which have appeared in the various editions of the *Encyclopaedia Britannica* and they will probably consult those of the new fourteenth edition with especial interest in view of the fact that emphasis is laid therein on the history and elementary subjects of mathematics. In view of the very rapid growth of human knowledge during recent decades one cannot reasonably expect to find in such a general work a complete account of the recent developments in the subjects treated. The authors of the various articles frequently refer to the limitation of space as an explanation of omissions of important relevant matters. It is quite likely that in some cases they presented only one side of a question when they would also have presented other sides thereof if more space had been available. Hence the following supplementary observations should be regarded as simply additions which seemed to the present writer as especially relevant as regards the interests of teachers of secondary mathematics.

Under the term "Algebra," volume 1, page 607, there appears the following statement: "Italy was the centre of learning and her scholars devoted much attention to solving the cubic equation. The latter solution was finally effected, with substantial completeness, by Tartaglia (1535) being published by Cardan in his *Ars Magna* (1545). The biquadratic was solved by Ferrari (1540) a pupil of Cardan's and was published by the latter in the same work." It would seem desirable to add to this quotation some remarks relating to the earlier work with respect to the solution of the cubic equation by Ferro J. Tropfke regarded this earlier work so important that he called the formula which is commonly called "Cardan's formula" by the name of "Ferro's formula." Cf. *Geschichte der Elementar-Mathematik*, volume 3 (1922), page 75. It would also be interesting in this connection to consider the article by G. Eneström, published in volume 7 (1906) of the *Bibliotheca Mathematica*, page 38, where the question whether Tartaglia obtained his solution of the cubic equation from Ferro is considered at some length. The contributions made to our present knowledge as regards the solution of the

cubic equation since the time of Tartaglia are naturally very substantial.

In view of the fact that Ferrari was born in 1522, the date in the given quotation implies that he was only about 18 years old when he discovered the solution of the biquadratic equation in the sense that he used a general method but failed to comprehend all the difficulties involved therein. Hence this date is of special interest since great mathematical achievements at such an early age are seldom found in the history of our subject. It may therefore be helpful to the reader if we note here that this date is not in agreement with the implication of a statement by J. Tropfke to the effect that Ferrari was not yet 23 years old when he discovered this solution. This statement appears on page 80 of the volume due to J. Tropfke which was noted in the preceding paragraph. Even 23 is an early age for such a remarkable mathematical feat but it is not nearly so striking as 18. In referring to this discrepancy the present writer merely aims to note that there seems to be a difference of opinion in regard to the age of Ferrari at the time when he made his well known contribution towards the advancement of mathematics, and that on account of his youth this difference is quite significant.

On the same page as the quotation noted above there appears the following: "Elementary algebra may be said to have been substantially completed by the close of the 17th century, by which time higher algebra especially through the progress made in the solution of equations, symmetric functions, and series had already begun to rank as a special branch of mathematics." Since the term elementary algebra is used with widely different meaning it is somewhat difficult to determine what this quotation is expected to convey. Probably all would agree, however, that negative numbers should be treated in elementary algebra and hence the statement that the mathematics of the eighteenth century suffered because of the fact that a generally satisfactory introduction of the negative numbers was then yet missing exhibits another side of the question involved in the quotation under consideration. This statement appears on page 78, volume 2 (1921), of J. Tropfke's *Geschichte der Elementar-Mathematik,* and is very interesting because it exhibits the importance of sharp distinctions in the history of elementary mathematics. Since Euclid used the fact that a subtracted number multiplied by a subtracted number gives an added

number, and Diophantus stated this fact explicitly, the reader might at first be surprised to find that even in the eighteenth century some well known mathematicians including R. Simson (1687-1768), did not accept the use of negative numbers as legitimate.

The history of negative numbers is especially interesting to teachers of mathematics because it illustrates a somewhat common situation in mathematics; viz., that special cases frequently become much clearer after the more general cases in which they are included have been developed. The negative numbers are obviously included under the common complex numbers which began to receive a satisfactory treatment at about the beginning of the nineteenth century through the publications of Caspar Wessel, C. F. Gause, and others. These publications exhibited the fundamental fact that as a multiplier a complex number has two distinct properties. One of these affects the modulus of the multiplicand just as in the case of positive numbers, while the other affects the amplitude of the multiplicand. This dual property is found also in the negative numbers when they are used as multipliers, and after it was clearly understood as regards the common complex numbers the legitimacy of the operations with the negative numbers became evident as a special case. The light thrown on elementary algebra by the advances in the more advanced parts of algebra since the close of the 17th century is alone sufficient to exhibit the fact that there is a serious other side to the question raised by the quotation under consideration. Some of the rays of mathematical light penetrate the entire subject.

To exhibit more fully the difficulties involved in determining the relative part of our modern elementary algebra which antedates the close of the 17th century we may add here that if we take as a standard the material which appears under the term algebra in the Weber-Wellstein *Enzyklopädie der Elementarmathematik* or in the *Enciclopedia delle Matematiche Elementari* much less than one-half of our modern elementary algebra was developed before the close of the 17th century. On the other hand, if we take some of our most elementary text-books on this subject as a standard it would follow that substantially all of it was developed before this date. Hence it results that the quotation under consideration is one of the many historical statements which those who are already familiar with the history of mathematics will read with some satisfaction but

which convey no accurate information to those who are unfamiliar with this history. It might be argued that the standards set by the noted encyclopedias of elementary mathematics are too high but it is to be hoped that many of the readers of the new edition of the *Britannica* also have high standards and that this work will contribute towards the elevation of our standards as regards mathematical work. At any rate it should be of interest to consider the other sides of the quotation under consideration and the futility of historical remarks involving terms with a very wide range of meanings unless the sense to be ascribed to these terms is explicitly noted.

Under the term "Arithmetic," volume 2, page 356, there appears the following statement: "The fact that twelve is scientifically a more convenient radix than ten (having its half, third, and fourth easily expressible), seems to have led to the use of eleven and twelve instead of oneteen and twoteen after which the denary scale is followed." On page 5 of volume 1 (1921), of J. Tropfke's *Geschichte der Elementar-Mathematik* it is stated that the word eleven arose from *ein-lif* = one over ten, as twelve arose from *zwo-lif* = two over ten; both do not point therefore to a system to the base 12. It may be added that under the term "Twelve" in Murray's *English Dictionary* it is stated that the word twelve is of uncertain origin but it is generally considered that it denotes two left or remaining over ten. If these views are correct the terms eleven and twelve are based on the radix ten and do not point to the possible radix 12. This is of considerable interest in view of the fact that conflicting statements relating to the origin of the words eleven and twelve are somewhat common in the literature relating to elementary mathematics and teachers are naturally anxious to be able to tell their students where they can find these statements and what the most reliable conclusions are as regards this point.

On the same page as the preceding quotation there appears the following statement: "To broaden the concept so as to include among fractions such cases as 2/2 and 3/2, and especially such fractional forms as have fractions for numerator or denominator, did not occur to arithmeticians until modern times." This quotation is perhaps more remarkable than those which we considered above in view of the fact that in the well known ancient Egyptian work by Ahmes the numerator is frequently a fraction and in Greek mathematics the numerator is often a mixed number. Cf. J. Tropfke, *Geschichte der Elementar-*

Mathematik, volume 1 (1921), pages 120 and 121. On page 16 of the *Rhind Mathematical Papyrus* by T. Eric Peet (1923), there appears the following sentence: "What is more, there are at least certain cases in which it is obvious that a fraction with numerator greater than 1 was conceived and that very clearly." This seems to be decidedly in disaccord with the quotation under consideration.

It was not our aim to furnish here a long list of quotations from the *Britannica* in which only one of several sides supported by various recent writers is presented, and which relate to questions of special interest to teachers of elementary mathematics. Such teachers are naturally very much interested in the reliability of standard works of reference as regards their own subject and the few quotations which were considered above may perhaps suffice to encourage some of them to examine with greater care some of the other statements found in the work under consideration. The main object of such an examination should obviously not be to find faults but rather to determine whether a reasonable amount of care was exercised to present the subject in such a manner that the average reader is not misled. In the brief discussions of the quotations cited above the present writer aimed merely to present the facts and to allow the reader to form his own conclusions as regards which of the noted views is the most reliable. It may, however, assist the reader to state here that in the opinion of the writer the views expressed in the given quotations should be modified in order to avoid misleading the average reader notwithstanding the great value of many of the mathematical articles of this work.

A reason why the students of mathematics who read only English should be encouraged to consult such general encyclopedias as the *Britannica* is that we do not possess in our language special modern mathematical encyclopedias like those cited above. The latter of these two encyclopedias of elementary mathematics is in Italian and only the first part of volume 1 has yet appeared but the second and concluding part of this volume is expected to be published during 1930. Two additional volumes, devoted to geometry and to applied mathematics (including the history and teaching thereof) respectively, have also been announced. It may serve to explain a somewhat singular situation if we note here that this encyclopedia was announced in the present writer's *Historical Introduction to Mathematical Literature*, 1916, page 279, while the first part

thereof which has been actually published bears the date of 1930. In this particular instance it can therefore not be said that this *Historical Introduction* was behind the times when it was published. As the plan to publish such an encyclopedia of elementary mathematics in Italy was inaugurated at least as early as 1909 more than twenty years elapsed from the time when this plan was announced till the first part thereof was actually published.

ADVANCED CHEMISTRY FOR TEACHERS OF SCIENCE.

Announcement is made by the University of Wisconsin Extension Division of a new course in Advanced Chemistry, No. 117, which is of interest to teachers of the physical sciences, particularly teachers of chemistry and physics in high schools.

Some of the most outstanding recent advances in science have been made by the chemists. The widespread implications of these advances challenge the intellectual interests of teachers generally quite as much if indeed not more than they do the attention of persons engaged in the applied affairs of life. The work of the world is inextricably involved by these new conceptions and methods. While we find that teachers as a rule keep abreast on their own initiative, it is the purpose of this course to bring forward the latest advances in Chemistry development, to coordinate in a systematic way and make a unity of the new knowledge with the older conceptions and methods. The subjects of crystals, crystallization, composition of compounds, and Werner's theory are thoroughly covered. Appropriate laboratory directions to illustrate the principles involved are provided.

The discovery in 1911 by Dr. M. Laue that the regular arrangement of atoms within a crystal would defract and reflect X-rays and that these defracted rays could be used in determining crystal symmetry awakened anew the chemist's interest in crystals. The work of Dr. Laue and others has confirmed the laborious efforts of those who spent their lives in building up the concept of space lattice to interpret the external facetted forms of crystals. Professor A. H. Tutton points out that no definition of life has yet been advanced that will not apply to a crystal. The study of crystals and crystallization constitutes one of the most fascinating chapters in chemistry. Accompanying the work on crystals and crystallization is a study of valence and complex compounds that must be explained by the newer theories of matter when they are finally accepted.

The flexible possibilities of the course, as organized and conducted by Professor G. G. Town, Chairman of the Department of Chemistry in the University Extension Division, afford the teacher of science stimulation and suggestion, material and methods for the improvement of his own courses. It gives as well a rounded coordination of the present day status of the science of Chemistry. The course is particularly intended for the alert teacher of science, who, although he has kept abreast in his reading, may not have recast the new advances into an effective and satisfactory unity.

For further information write to: W. H. Lighty, Director, Department of Extension Teaching, The University of Wisconsin, Madison, Wisconsin.

THE AGE OF MAMMALS AND MAN—A NEW UNIT IN HIGH SCHOOL BIOLOGY.

By W. W. McSpadden, *Supervisor of Sciences, Austin Public Schools*, and Mildred Pickle Mayhall, *Instructor in Anthropology, University of Texas.*

In general the course of study in high school biology gives little attention to the study of mammals and man. The reasons for this are many. A great deal of time is necessarily spent in explaining fundamental biological principles. In a genetic approach to the study of biology the simpler organisms will be studied before the more complex are dealt with. Laboratory materials and equipment for the study of the simpler organisms are more easily acquired. Mammals, including man, the highest of vertebrates in the zoological classification, would come near the end of the course; and often there is not enough time allowed for more than a brief treatment of this important study. In many cases new teachers are not familiar with advanced work in biology, having had only a brief training in the subject, and do not feel competent through lack of advanced work or general reading to deal with the subject matter that may be included about mammals and man. This is particularly true in regard to mammalian paleontology.

There are some teachers who may believe that the study of man should not be included in a high school course. The writers believe that the inclusion of the material presented in the following unit has a very definite place in a study of high school biology, since man has a place in the past, present, and future animal world. The unit is of great value in dealing, not exhaustively but briefly, with subjects that have social significance for every high school student of biology. Every individual who wishes to know something of the past history of man should have his normal curiosity satisfied to the best of the teacher's ability and in keeping with scientific facts. It seems to the writers that the continuity of change may be illustrated in a brief but adequate way by the facts of mammalian and human paleontology. Furthermore, they have found this to be of great interest to high school students. Such a background is of value for the larger applications of heredity, evolution and eugenics and the social aspects of biology.

Much of the ignorance and dogmatism encountered in many communities today in regard to questions dealing with evolution and eugenics is the result of lack of knowledge of biological

principles and lack of information regarding the origin and progress of man. Adequate biological instruction in high school would do much toward furthering a saner view of such questions.

The unit outline here presented is of necessity brief, but it may be enlarged upon by the teacher as he sees fit or as the interest of the class may dictate.

The Age of Mammals and of Man

I. The periods of the Cenozoic Era. Chart from "How Old Are Fossils" p. 11.
  A. Tertiary
    1. Eocene
    2. Oligocene
    3. Miocene
    4. Pliocene
  B. Quaternary
    1. Pleistocene (Ice Ages)
    2. Holocene (Recent)
II. The first appearance of mammals on earth (Mesozoic.) A. of M. 6-12*
  A. Development and culmination of mammals (Cenozoic)
    1. Mammalian types of the Eocene. A. of M. 12-21; P. and S. 929-932*
      a. Phenacodus
      b. Dinoceras
      c. Horse (Eohippus)
      d. Cat (Dinictys)
    2. The modernization of mammals—Oligocene. A. of M. 21-36; P. and S. 931
      a. Titanotheres
      b. Brontotherium
      c. Coenopus (rhinoceros)
      d. Baluchitherium
      e. Archeotherium (giant pig)
      f. Horse (Protorohippus)
    3. Miocene mammals. A. of M. 36-51; P. and S. 932-934
      a. Elephant (Trilophodon)
      b. Antelope (Syndoceras)
      c. Camel (Altacamelus)
      d. Horse (Mesohippus)
      e. Moropus (Transition type)
    4. Pliocene and Pleistocene mammals. A. of M. 51-64; Finger "Ice Age"; P. and S. 934, 956
      a. Glyptodont
      b. Sloth (Mylodon)
      c. Sabre-toothed tiger (Smilodon)
      d. Elephant, mastodon, mammoth
  B. Conditions leading to development of mammalian life
    1. Over specialization of reptilian life (Mesozoic)
    2. Advantages of mammals over their predecessors. Seers 94-105
      a. Warm blooded—adaptation to increasing cold of glacial epochs
      b. Greater activity—giving more protection
      c. Greater mentality—quicker adaptation for food-getting
      d. More highly perfected reproduction
  C. Types of mammals
    1. Monotremes
    2. Marsupials

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*A. of M. ("The Age of Mammals," Haldeman-Julius Blue Book No. 415), P. and S. (Pirsson and Schuchert, "Historical Geology").

3. Eutheria
   a. Placental mammals
   b. Advantages of placental reproduction. P. and S. 807, 927 ff

III. Development of primates and man. "Stone Age" 14-16; "Man and Ancestors" 7-13; P. and S. 962-963; McCurdy Vol. I.
  A. Fossil primates
    1. Eocene
       a. Notharctus—Lemuroid type
       b. Tetonius—Lemuroid type
    2. Eocene through Pleistocene—Mesopithecus (Simiidae)
    3. Miocene through Pleistocene—fossil anthropoids
       a. Propliopithecus—Fayum, Egypt
       b. Sivapithecus—Siwalik lake beds of India
       c. Australopithecus—Africa
  B. Pithecanthropus erectus—Pleistocene. "Stone Age" 17-19
    1. Discovery. "Man and His Ancestors" 13-16
    2. Significance.
  C. Fossil man. Osborn "Men of the Old Stone Age"; Seers "Earth and Life" 106-115
    1. Piltdown man. "Man and His Ancestors" 17-24
    2. Heidelberg man
    3. Ehringsdorf and Taubach races. McCurdy Vol. I
    4. Neandertal man. "Man and His Ancestors" 24-40
    5. Grimaldi man. "Stone Age" 42-46
    6. Brünn race
    7. Cro-Magnon. "Man and His Ancestors" 40-54; "Stone Age" 47-57

IV. The Stone Ages. McCurdy Vols. I and II; Osborn "Men of the Old Stone Age"
  A. Life of the Paleolithic (Pleistocene). "Stone Age" 1-62
    1. Development of culture. Seers "Earth and Its Life" 116-125
       a. Fire (Chellean-Mousterian)
       b. Evidence of life from river drift and caves
       c. Burial
       d. Art
       e. Religion—earliest traces
       f. Dress—evidences from use of needles
       g. Artifacts—weapons, utensils, implements
  B. Life of the Neolithic. Seers "Earth and Its Life" 126-137
    1. Races
       a. Long-headed (Dolichocephalic)
       b. Short-headed (Brachycephalic)
    2. Cultural development
       a. Use of polished stone and axe
       b. Hafted axe
       c. Pottery
       d. Weaving
       e. Religion—more highly developed
       f. Megaliths
       g. Burial
       h. Dress
       i. Domestication of plants—grains, fruits
       j. Domestication of animals—dog, horse, cow, sheep
    3. Types of Society
       a. Nomadic—herders (domestication of animals)
       b. Sedentary—agriculturists (domestication of plants)

V. Comparison of fossil man and modern man. P. and S. 960-977
  A. Home sapiens fossilis—Paleolithic
  B. Home sapiens—Neolithic and Metal Ages to today
  C. History versus pre-history
    1. Pre-history—Paleolithic and Neolithic
    2. History—Metal Ages (Bronze, Iron, and Steel)

D. Progress in culture—civilization
E. Progress in man—civilization
F. Aspects of deterioration in civilization

Summary of the Outline

The Cenozoic era comprises two periods, the Tertiary and the Quaternary. The Tertiary includes the Eocene, Oligocene, Miocene and Pliocene Ages; the Quaternary includes the Pleistocene and the Holocene or Recent Ages. The Cenozoic era witnessed the rapid rise of mammalian life which had its first appearance towards the end of the Mesozoic era.

The mammalian life of the Eocene may be illustrated by the study of such forms as the Phenacodus, Dinoceras, Eohippus and Dinictys. In the Oligocene, Miocene and Pliocene, mammalian life is found to diverge and to show many specializations. The evolution of the horse from the small Eohippus, slightly larger than a small dog, to the modern day horse (Equus) is well worked out and shows progressive change and adaptation to environment. Such changes are to be seen in other mammals, such as the elephants, antelopes, camels, etc.

With the Pleistocene we notice many animals that approach in type and structure the animals of the Recent. Many of the archaic types of the Tertiary are found to be extinct. With the passage of the last Ice Age and the beginning of the Recent we arrive at present day types of animals.

The great development of mammalian life of the Cenozoic began with the proto-mammalian life of the closing Mesozoic. Following and perhaps contributing to the extinction of the great reptiles of the Mesozoic, mammals began their rise. Overspecialization, climatic change, internecine warfare, and the egg-eating mammals all contributed to the extinction of the reptilian life. Mammals showed many advantages over reptiles by their greater activity and greater intelligence. The placental mammals superseded the earlier monotremes and marsupials of the early Tertiary.

The primates comprise the lemurs, monkeys, anthropoids and man. The earliest lemuroid types are found in the Eocene strata of North America. Monkeys were widespread in their distribution from Tertiary times through the Quaternary. Fossil anthropoids have been found in many localities, notably the Siwalik lake beds of India.

In 1891, Pithecanthropus erectus or the Trinil ape-man was discovered in Java. While primitive, the fossil shows a tendency

to man-like qualities and a brain capacity greater than that of any living anthropoid. The Eoanthropus dawsoni or Piltdown man is another early representative of the proto-human stock. Evidence at present points to Asia as the home of early man, with the time of origin probably Pliocene or late Miocene. Western Europe shows a progression of fossil races of man and indices of early culture. Some of these races are the Heidelberg, Ehringsdorf and Taubach, Neandertal, Grimaldi, Brünn and Cro-Magnon. The Cro-Magnon race was undoubtedly physically and mentally superior to other Paleolithic races as evidenced by their physical and cultural remains. Artifacts and cave drawings give us much information in regard to their life and habits.

The cultural ages of man may be divided into the Stone and Metal Ages. The Stone Ages comprise the Eolithic or Dawn Stone Age, the Paleolithic or Old Stone Age and the Neolithic or New Stone Age; the Metal Ages comprise the Bronze, Iron and Steel Ages. The Paleolithic witnessed the early beginnings of the cultural life of man; such as the use of fire, burial, art, religion, dress, and the fashioning of weapons and implements. Cultural evolution proceeds in the Neolithic with advances in the technique of making artifacts and with the addition of domestication of animals and plants, pottery, weaving and other traits.

The study of fossil man and his culture gives a basis for the understanding of present day man and his social life. Many traits of culture may be traced back to prehistoric times before the finding of written records. Civilization is seen to have its roots in prehistory, and present day races of man show the results of a long continued physical and societal evolution. One of the most interesting aspects of this progress has been the development of the human brain which has made man the dominant form of mammalian life.

Method of Presentation

In the presentation of the unit to the class the instructor should briefly explain the purpose of the study of such material as that found in this unit. In the presentation it has been our experience to find that many questions will arise spontaneously among members of the class. Especially is this true if the instructor asks a few leading questions. Students are eager to know about such things. Thus, this unit, differing from some of

the other units in the biology course, starts off with enthusiasm and interest.

A mimeographed outline is handed to the student. This gives him a basis upon which to work out the material for himself. All references mentioned in the unit are available to the student, either in the classroom or in the departmental library.[1] Supervision of study then proceeds with the outline as a guide.

In our early attempts at the construction of this unit it was found necessary to introduce the concept of time that is so essential to an elementary understanding of the continuity of change. Consequently we have used a rather strict geological chronology in the unit as it stands. It is mainly in this respect that the unit differs sharply from those in other courses of study. We believe this to be a distinct advantage.

To make the unit more interesting and at the same time to obtain clarity and meaning, lantern slides are used. Students do not take the same interest in some never-before-heard-of extinct animal when the name only is mentioned, but when slides showing the skeletons and reconstructions of the animal mentioned are flashed upon a screen in front of the class room, interest is readily apparent. Not too much value should be placed upon reconstructions, but they certainly are of value in helping young students visualize animals of the past. Most of the lantern slides were obtained directly from the American Museum of Natural History. Some slides that were unobtainable were made in our own laboratories from textbook figures and illustrations from magazines and journals.

Slides showing the actual remains of fossil man are accompanied by pictures of reconstructions of these forms. In the unit which precedes this one, the student has become familiarized with the processes by which fossils have been formed.[2] Thus the fossiliferous remains of early man are easily explained. Slides of caves and various stations in Europe aid in making this clear. Among the most interesting of the many slides used in visualizing the cultural life of the Paleolithic are those of the murals by Charles R. Knight found in the American Museum of Natural History. In addition to the use of slides, there are several motion pictures available.

Charts, models and skeletons are useful in comparing modern day mammals and man with those of the past. Books, pamph-

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[1]A bibliography useful to the instructor will be found at the end of this article.

[2]The preceding unit is called "Animals of the Past."

lets, and magazine articles should be used as much as possible. Few biology texts treat of this subject.[3] Books dealing with paleontology and anthropology are too advanced and too expensive for general use. For the use of the students we have found it practicable to purchase several of the Haldeman-Julius "Little Blue Books" in multiple copies. These little books contain much useful information and are quite readable for high school students. Museum pamphlets have likewise been used.

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[3]Kinsey, Alfred C., "Introduction to Biology" is an exception.

TRIGONOMETRY — CONVINCING MATHEMATICS FOR THE NINTH GRADE PUPIL.

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The subject of graphs only exceeds that of trigonometry in vitalizing ninth grade mathematics. The former subject is broader in its application and correlations in mathematics and in other fields. It educates generally, over a broader field and may be expressed by and serves many and varied interpretations. Yet the latter subject creates pupil interest and appreciation of mathematics of a very genuine and lasting sort. Moreover the processes of trigonometry, to the pupil, are more closely allied with much of the rest of ninth grade mathematics, and hence lend interest to the other topics, whereas the subject of graphs, by its very nature, being so new and different to the pupil seems to him a subject apart, rather distinct and almost remote from the other topics. To him it is a matter of graphs in contradistinction to other phases and topics of mathematics. The fact that the object of his pursuit is a drawing, something pictorial, an entity constructed with instruments, makes the graph, to him, regardless of its presentation, a chapter of mathematics rather than an interpretation or pictorial aspect of formulas, equations, or statistics, throughout mathematics. Then since the trigonometry of the right triangle is found to be so convincing by our young people, since its problems are so practical, since the subject is found upon careful examination to correlate so well with other phases of elementary mathematics, possibly we, as teachers, should give it greater attention, greater interest, greater study and emphasis.

At the very outset, in the first presentation of the subject, the pupil is a bit flattered and sets out at once to meet the test of mastering a subject regularly regarded as a pursuit of fourth year high school and college students. The word itself, "trigonometry," "trigon" being the Greek word for "triangle" and the suffix "metrein" meaning "to measure," is a word for thirteen or fourteen-year olds to conjure with. The lad expands his chest while boasting of his new study to his elders, who, unless they were trained in some of the classical or scientific schools of Europe, did not study trigonometry until the age of seventeen or so, if at all. Hence we are put to no effort to elicit the interest of our young people. If we merely suggest the type of problems solved by numerical trigonometry, the very nature of them

convinces the youth at once of the usefulness of the subject. What child is not interested in measuring the height of the school tower, the flag pole, a steeple or a cliff without climbing? To be able to measure the distance to the opposite shore of a lake or to a ship at sea, without crossing over to it, and moreover with the assurance that the problem involved is a simple algebraic and geometric problem, would be an accomplishment to anticipate. Then, our psychological situation is readily created and sustained.

We may not approach the subject until the pupil is experienced and practiced in the subjects of ratio and proportion and moreover has a clear conception of, and is familiar with similar triangles and their properties. He should also use the protractor with ease. Then we are ready to define the tangent ratio, using the term "ratio" because of its connotation, rather than "function." A ratio is always a quotient, an indicated division, whereas a function—at best a difficult word for high school pupils—may represent any operation. Parenthetically, it is rather unusual for fourth year students of mathematics to voluntarily incorporate the word "function" into their speaking vocabularies, as much as some of them delight in polysyllabic words, though the word is a part of their reading vocabularies, and they are able to define it, and illustrate it easily and readily. Perhaps we should pause a moment to decide just what we mean when we say the tangent ratio of an acute angle "is defined" as the quotient or ratio of the leg opposite the acute angle to the leg adjacent to this acute angle, each leg being measured in the same unit. Moreover we should convince pupils, by the use of similar triangles, that for a given angle this ratio is always the same regardless of the size of the right triangles of which this given angle is an angle. Then we apply our definition to numerous acute angles of right triangles in various positions, discovering that the tangent of the complementary acute angle of a given angle is the reciprocal of the tangent of the given angle. It is well, however, to confine our attention, just here, to the tangent, reserving the cotangent function for the advanced course in trigonometry, so as to avoid confusion.

Then we take up the study of a three or four-place table of natural tangent functions, possibly showing the functions at intervals of 10′, which should, however, for elementary work, be printed continuously through 89°50′—probably not 90°—so as to obviate the need of reading the table across the bottom and

up the right side for angles greater than 45° and less than 90°. The theory and training required in order to use tables shortened to 45°, such as are regularly used in the advanced trigonometry, are not justified here. Having learned to read our table, we use it at once in problems having given in each right triangle a leg and an acute angle. No solution should be accepted without a sketch showing the conditions of the problem, a small, neat, and accurate mechanical drawing, for the drawing is usually the key to the solution. The pupil who has difficulty with a problem, in the advanced or introductory work in the solution of triangles, is almost invariably the one who is trying to visualize the figure attaching to the several parts their respective values mentally. The ability to acquire the mental capacity of projecting in the mind such a figure and thus of solving the problem almost entirely without a pencil is one of the fine goals of mathematics, but not one to be aspired to in an introduction to the subject of trigonometry.

Having become fairly adept in the solution of this type of problem and in the use of the table, we should turn our attention to the use of the tables to find an angle, given the tangent of the angle. One questions the advisability of teaching interpolation to a group of the ninth grade unless the class is exceptional in ability, although some of the text-books raise no such question. Hence one should select examples with great care or, better, instruct pupils in approximating or rounding off or reading to the nearest angle given in the table.

Now, having acquired skill in the use of the tangent ratio, a clever youth will, no doubt, observe that occasions will arise where the tangent will be of no use. That is, the hypotenuse and a leg of the right triangle may be given. However the rejoinder will likely come that the Theorem of Pythagoras will then solve our example. But suppose the parts given are an acute angle and the hypotenuse. Then our resources are at an end. Hence the need of a new ratio, the sine ratio and its definition. We continue with the application of the definition, the study of the sine table and use of it, much as we developed the tangent.

Without continuing further it might be well at this point to work out a table of sines for angles at intervals of 10°, using for equipment, in our experiment, a large sheet of coordinate paper, compasses and protractor. We draw the OX-axis or initial side of the angle along the bottom edge of the paper devising such a scale along OX as to make the radius, OX, a multiple of

10, if possible and yet use as large a scale as our paper permits. Then with the protractor we draw a line OX, so as to make an angle of 10° with OX, OX,, 20° with OX, etc., continuing to 90°. We make the terminal sides of these several angles the length OX, i. e., 10 units or a multiple of 10 units. We draw a large quadrant with O as the center and OX as the radius. Then we read the ordinate of the point X, or the length of XX, from our graph to as high a degree of accuracy as seems consistent with the size and scale of our graph. We divide the length of this ordinate by the length of OX, which equals OX, measured in the same unit as the ordinate and preserve this ratio, associating it with the angle 10°. We construct a two-column table, one column of angles measured in degrees and the other of the corresponding sine ratios, recording 10° and the corresponding ratio, 0.17, let us say, for the first variable pair in our table. We continue this process until we have completed the table. We have now our own table of sines developed by us. It seems that pupils, even in a fourth year course in trigonometry do not actually understand a table of natural functions until they have constructed one. They sincerely believe that they understand. They talk sensibly about it, but one day it becomes apparent to the instructor that he and they have been inadvertently misled as to their conception of a trigonometric function. High school pupils, to comprehend trigonometric tables must at some time construct one. After so doing the subject is no longer vague. Limiting values are readily comprehended. In the advanced work, when the subject of logarithms is taken up, the logarithmic trigonometric functions are easily understood.

After this very careful treatment of the sine ratio comes a similar experience with the cosine, though the problem of developing a table of cosines will probably not be found necessary.

In this study of the triangle the area formula will likely be reviewed and applied. Similar triangles with their properties will, no doubt, be studied again and in more detail than previously though such work may be carried on, needless to say, without the use of the trigonometric functions. In this connection pupils are much interested in the historical account of the experiment of Thales of Miletus who lived in the sixth century B. C. He amazed the king of Egypt by determining the height of a pyramid by indirect measurement, that is, by measuring its shadow and comparing the length with that of a small object of known

height. In so doing he anticipated the properties of similar triangles, the theory of which was not however fully developed until centuries later.

Another interesting triangle problem of history is the one concerning Napoleon and one of his officers. On one of his military expeditions Napoleon required of this officer that he measure the width of a stream, though he had no instruments for doing so and there was no means of crossing it. It is recounted that the officer stood erect on the edge of the bank facing the opposite shore. Then he lifted his military cap, readjusting it on his head, by tipping it down over his eyes, until he was just able to see the edge of the remote bank under the visor of the cap. Keeping his head in the same erect position he pivoted through an angle of 90°, with his body still erect, so that he was then looking in a direction parallel with the course of the river. He then sighted that object on the bank, on which he stood, which was just visible under the visor. He noted the object. Then he paced the distance from his position to the object. That distance was the width of the river.

One finds the problems of trigonometry interesting, practical and varied. They must meet these qualifications for pupils and instructors alike appreciate them. Moreover even the humorists, such as Stephen Leacock, have found nothing droll or diverting about them. The following are suggestive:

How far from the bottom of a viaduct must the approach begin if the viaduct is 40 feet above the level of the road leading to it and the angle of elevation of the road is to be 9°?

A dam 30 feet high forces water in a river back a horizontal distance of one half of a mile. What is the slope of the ground?

The length of a kite string is 500 feet. Assume that the string is a straight line. It makes an angle of 40° with the level ground. How high is the kite?

The periscope of a submarine is seen at an angle of depression of 18° by the look-out in a battleship's crow's nest, which is 80 feet above the water. How far away is the submarine?

Often one finds in his class the youthful relative or friend of a surveyor or of an engineer. This latter person can sometimes be induced to bring a transit and steel tape to school and give an interesting talk on practical trigonometry. He, with the class to verify his records, actually measures and collects sufficient data in the immediate neighborhood of the school for the indirect measurement of the height of the flag pole or tower.

Problems take on reality after one has actually seen the methods of leveling a transit, after he has used the telescope of a surveying instrument, after he has stretched and read the steel tape, after he has personally read the angle of elevation through which the telescope has been turned and after he has made allowance in his subsequent calculations for the observed height of the transit.

One pupil of third year mathematics who had had no instruction in trigonometry told his instructor that he had been trying, "for two years," to solve a problem involving an angle. His chief avocation was tennis. He had been endeavoring to improve his service stroke for years. His aim was to find that angle at which, from his customary height of service, the ball would just graze the net, then to find the consequent distance from the net at which the ball would strike the court. If he found that distance to be altogether satisfactory, that is, consistent with his theory concerning service in tennis, he anticipated taking a position at that same distance from a wall, then serving balls, from his customary height, so as to cause the balls to strike the wall at the line where the wall met the ground. Much practice of this sort, with speed, would improve his service, he argued. The angle and subsequent distance, arrived at, might suggest increasing or reducing the height of his service. This was the real problem of a lad, now in high school, struggled over for months, due to the fact that he had never been instructed in the tangent ratio and the use of a table of natural tangent functions.

Let us consider, now, some of the cross contacts brought about in the study of the trigonometry of the right triangle. It correlates arithmetic, algebra, and geometry in its use of trigonometric tables and tables of square roots and squares in numerical substitution, in the application of geometric theorems and formulas, in the use of diagrams and graphic interpretations. It correlates mathematics with mechanics and elementary surveying. Its applications involve the construction of buildings, bridges, and railroads, map making, elementary astronomical work and navigation.

The pupil experiences concerned in the study of the trigonometry of the right triangle include: an insight into the mathematical method of indirect measurement by drawing to scale, using triangles of reference; the construction and use of statistical tables with the precision, and "rounding off" of results to a degree of accuracy consistent with the least accurate of the data

involved in the problem; practice in the endeavor to arrive at a prior estimate which serves as a guide and "rough check" upon the later meticulous solution of the problem; an appreciation of the short cuts impossible without trigonometry, as in the case of the solution of a right triangle given any two sides; and greater appreciation of the concepts of constant, variable, and functionality. These then are some of the experiences in the field of mathematics. Experiences in associated fields have been suggested before.

Surely the subject of numerical trigonometry is such as to contribute to the preparation of the young person to become a civic, social and economic asset to the community and to himself. It convinces the pupil of utility, of practicability. It arouses and develops latent interest and power. Moreover it is not without cultural value. These are indeed some criteria for justifying the place of elementary trigonometry in ninth grade mathematics.

BACKGROUND AND FOREGROUND OF GENERAL SCIENCE.

No. IX. INSECTS THAT CARRY DISEASE GERMS.

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In article number eight of this series some methods of approach to the study of microscopic life were suggested. An interesting and valuable unit of study, which would introduce a number of the most dangerous examples of microscopic life, is a study of insects that carry disease germs.

Insects may carry germs mechanically as bees carry pollen; or they may carry the germs more as bees carry nectar in their honey stomach, making a necessary change in what they bear before delivering it. An example of the first would be the fly alighting on germ containing filth and later crawling with its dirty feet over food. An example of the second method is found in the transfer of malarial germs, where one of the stages in the life cycle of the germ must be spent in the body of the mosquito.

Though studies in germ life naturally began in Europe, where science was already well advanced, America has not been idle in the great task of finding and combatting the bacterial causes of disease. The first case in which it was proved that an insect could be a carrier of a deadly germ was studied by an American, Theobald Smith. In 1890 Smith proved that Texas fever among

cattle is caused by germs given to the cow by ticks that live upon her.

Southern cattle have these ticks but are immune to the disease. But if Northern cattle are taken South they die. Or if Southern cattle are brought North they give a disease they do not themselves seem to have to the Northern cattle. Smith first showed that if the Southern cattle were picked free of ticks before being mixed with cattle of the North no harm was done. But he could not understand how ticks that lived all their life on the same cow could give the disease to others. When a tick drops off on the ground it dies after having laid its eggs. Then the young ticks crawl up the legs of other cattle and give them the disease though they have not been on diseased cattle.

The mystery was solved when he found the ticks hatched from eggs in the laboratory were capable of making an animal sick, and, strange to say, that this cow's blood would be full of the same kind of disease germs he had found in all animals sick with Texas fever.

Evidently the germs were given by the mother to the eggs, and so transferred to whatever animal was bitten by the young ticks.

Once the scientific world knew for a certainty that an insect can carry disease germs rapid progress was made. Other insects than the cattle tick came under suspicion, some of them, as it proved, under very just suspicion. One of the first to be indicted, and finally convicted, was the mosquito.

In India and in other tropical countries malaria has always been a dreaded sickness. It is there a worse form of what in the United States is called "ague" or "chills and fever." Long ago quinine was found to be a remedy, but the cause of the trouble was not known. The name malaria, meaning "bad air," suggests that the cause was supposed to be that imaginary gas called "miasma" that was thought to rise from swamps. They had not then seen in the clouds of mosquitoes rising from such breeding places the real miasma.

A government physician in India named Ronald Ross was one of the first to do the necessary detective work to track down the guilty insect. Ross who had strong reason to suspect that the anopheles mosquitoes were distributing malaria germs caught some of them and found them armed with the deadly weapons of death. Dissecting the mosquitoes he found the

tiny germs developing in the walls of the stomach and then working their way to the salivary glands where they would be ejected and passed into the blood of the mosquitoe's victim when it was bitten.

Ross experimented with birds, which he found were capable of taking malaria. A few days after the mosquito was allowed to bite a bird germs began to multiply in the bird's blood, and it became sick. This discovery was made in 1898.

In the same year an Italian Zoologist by the name of Grassi was studying malaria in Italy, where it was very prevalent. He too was on the track of the mosquito. Grassi being a zoologist was familiar with the various kinds of mosquitoes of which there are many. The culex our commonest variety he found to be harmless, but where malaria abounded there always were found the anopheles.

This however, was not proof enough for Grassi, he wanted something more definite. So he went to the most malarious localities he could find and caught the female anopheles mosquitoes. The males do not bite. These he allowed to bite patients in the hospital who had never had malaria. When they developed malaria Grassi gave them quinine to cure them, and went on with his experiments.

Combining such damaging evidence as Ross and Grassi and later experimenters have collected the case against the mosquito is perfect. We do not get the ague by eating cucumbers or breathing miasma but by being bitten by an anopheles mosquito.

The microbes cannot pass through all the cycles of their life history without spending a part of it in the body of the mosquito. The case is somewhat similar to that of an insect. If it cannot find a suitable place to lay or pupate it cannot go through the various stages of metamorphosis necessary to its life. For example since the prairie sod of the western plains was broken by the plow the grasshopper scourge is a thing of the past for the insect has no undisturbed nest for her eggs.

Detecting the cause of malaria opened the way for at least its partial control. The story of Gorgas drying up the swamps of Panama or treating them with oil to kill the young mosquitoes is a story of victory which would not have been possible without this knowledge. The French had tried to build the canal, but while two thirds of their workmen were busy one third of them were constantly in the hospital, and later many of them in the cemetery.

More dramatic still was the fight in Havana against yellow fever. Another kind of mosquito called Stegomyia was found to be the cause and the sole cause of this, one of the world's worst plagues.

In 1900 an American army was camped in Havana and yellow fever was killing more men than had been killed in the Spanish war. General Wood had given orders to have the city cleaned up but there was no check in the disease. The cleanest American officer seemed as liable to contract the plague as the dirtiest native in the slums.

A yellow fever commission was appointed to study the disease and try to learn its cause. Dr. Walter Reed was made head of the commission.

Nothing but human beings would take yellow fever. Reed could not experiment on guinea pigs, mice, birds, or even monkeys as others had done in other diseases. Only one way was open and he must take that if he was to learn the cause and therefore the prevention of the plague.

So he got soldiers to volunteer to take the place of animals in the experiments. He also hired some of the inhabitants of the island to take the risk of getting the fever.

The mosquito was under suspicion as it had been in case of malaria. These were caught and allowed to bite fever patients, and then after some days were permitted to bite those who had volunteered or had been hired to submit to the risk. Not all of them were made sick, some were probably immune, but a large proportion of them were stricken a few days after being bitten. Dr. Lazear a member of the commission was bitten by a mosquito as he went through the wards of the hospital. He died a few days later.

The proof was now pretty strong but there was still a question as to whether or not the disease might be taken by contact with the sick, by handling their clothing, or in some such way.

Some of the courageous volunteers slept for several nights in filthy bedding in which yellow fever patients had died. They were none the worse for the unpleasant experience.

Lest these men might have excaped by being naturally immune one of them next allowed mosquitoes to bite him. His lack of immunity was soon shown for in a few days after being bitten he came down with yellow fever and nearly died.

Now war was made on the mosquitoes of Havana and their breeding places, and within three months the city was

for the first time in many years free of yellow fever.

Since that time in all parts of the tropical World where yellow fever had been such a plague it is little feared. If a case occurs the patient is kept screened so he cannot be bitten by mosquitoes which would thus be given the germs to distribute to others. Unless they can bite a sick person they are harmless.

Bubonic plague, the terrible epidemic disease that has been known as *the* plague for some two thousand years has also been found to be spread by insects. In this case it is to the flea that the danger has been traced. There may be other ways in which it can be transmitted from one person to another, as by getting some of the germs from a sick person into a cut or scratch on the hand, but fleas are supposed to be the chief distributing agents.

Rats, squirrels, and several other animals will take the disease and so can be used for experiment. It was found that if healthy rats were shut up with rats carrying the germs the well ones remained well if no fleas were present but if fleas were permitted in their cage the disease went from one to another.

Rats are a great source of danger if there is any bubonic plague about for fleas go from sick men to rats and from rats to well men. The sick can be quaranteed, but rats in the streets cannot be.

Several times within a generation bubonic plague has broken out in coast cities of this and other countries but knowing the cause the disease was soon checked. Systematic war was made upon rats.

So this plague sometimes called "black death," which at some of its outbreaks killed millions of people in Europe and the East during the Middle Ages has been brought under control.

Typhus fever has been another of the terrible epidemic diseases of the world. Its exact cause was long a mystery but it was known to flourish where hygenic conditions were worst, where surroundings were most filthy. So it was often known as "jail fever" and "camp fever." It is said to have killed more people than the sword during the "Thirty Years War," and was the terror of Napoleon's soldiers. The last outbreak was during and after the recent "World War."

As one might almost guess from the conditions in which typhus spreads most rapidly the insect responsible for carrying it from one to another is the louse, or so-called "cootie" of the trenches. In normal peace times and among people of cleanly

habits naturally this disease does not often appear. Typhoid fever, though similar in name, is an entirely different disease with a different germ as its cause.

Such studies as those above serve as the best possible means of exemplifying the methods of science. But perhaps their chief value is to help in bringing up a generation who will support the efforts of their boards of health and commissions on hygiene. Public apathy and active opposition are best overcome by knowledge.

As a French leader of public opinion said, "Give light and the people will find the way."

ARE COROLLARIES INDISPENSABLE IN PLANE GEOMETRY?

By E. B. Cowley,
Pittsburgh, Pa.

Corollaries are a source of difficulty to many pupils. The definition "A corollary is a geometric truth easily deduced from another geometric truth," is of little assistance in answering the questions that arise in their minds. These questions are worthy of serious consideration:

1. Why is not the word corollary applied to every case in which one truth is easily deduced from another? For example: If the theorem concerning an exterior angle of a triangle is called a corollary of the theorem concerning the sum of the three angles of a triangle, why is not the theorem concerning the sum of the angles of a polygon called a corollary of this theorem?

2. If a new truth can be easily deduced from a corollary, why is it not called a corollary of a corollary? For example: The theorem concerning the three angles of a triangle can be easily deduced from the theorem concerning the alternate interior angles of two parallel lines cut by a transversal. Then the theorem concerning an exterior angle of a triangle is really a corollary of a corollary.

3. Is every statement called a corollary a distinct new geometric truth, or are some corollaries merely special cases of the general truth expressed by the theorem? For example: One of the nine corollaries of the theorem concerning the sum of the three angles of a triangle is, "In any right triangle, the two acute angles are complementary."

5. If a corollary is "easily deduced," why is it necessary to write out formal proofs of corollaries?

Teachers also have something to say regarding corollaries.

1. The movement to reduce the number of theorems in elementary texts will be defeated if corollaries are added to the theorems. For example: A recent text that has thirty-eight theorems in Book 1 adds twenty two corollaries.

2. It is claimed that by the use of corollaries it is possible to obtain briefer proofs. Is not this objective insignificant when compared with the mastery that a pupil gains by using the fundamental theorems over and over again?

3. It is also claimed that by the use of corollaries it is possible to have greater variety in the methods of proof. Is this desirable? Is not the defect in some texts the lack of emphasis upon a few methods which the pupil can comprehend and can apply to "originals"?

4. In the lists published by the College Entrance Examination Board, by the National Committee on Mathematical Requirements, and by the University of the State of New York, there are theorems and constructions, but no corollaries.

5. Would there not be a distinct gain in the elimination of corollaries in texts in elementary geometry, both plane and solid? Some of the corollaries are essential theorems. These should be called theorems. The others can be used as exercises.

SCIENCE QUESTIONS.

Conducted by Franklin T. Jones, 10109 Wilbur Avenue, Cleveland, Ohio.

Readers are invited to propose questions for solution or discussion—scientific or pedagogical—and to answer questions proposed by others or by themselves.

Please send examination papers on any subject or from any source to the Editor of this department.

What have you got? Send them in.

What would you like? Ask for it.

BIOLOGY TEACHERS.

The Big Question, No. 549.

Why did not some of you write to me immediately after the Central Association meeting in November and let me know *you wanted* a "Biology Number"? I heard about it but *you* did not tell me.

Please help me with some Biology material for publication. All I have is some dry old questions. Haven't the questions been the same for 20 years?

Some good LIVE stuff, please—living Biology, not the dead kind. What is it and where? I'll do my part; please help.—Editor Jones.

APOLOGIES AND ACKNOWLEDGMENTS.

The Editor of this Department has been compelled by press of business to neglect answers to many correspondents. This apparent discourtesy has been a regretted necessity. Among those neglected are:

H. D. Hatch, English High School, Boston, Mass.

Chemistry Students (per Lillian Scott), Bishop McDonnell Memorial H. S., Brooklyn, N. Y.
Vincent Crawford, Cloughbeg, Warrenpoint Co., Down, Ireland.
George Sergent, Tampico, Tampa, Mexico.
Glen W. Warner, School Science and Mathematics, Chicago, Ill.
Smith D. Turner, Goose Creek, Tex.
Prof. C. A. Reagan, Friends University, Wichita, Kans.
Margaret Joseph, Shorewood High School, Milwaukee, Wis.
R. T. McGregor, Elk Grove, Calif.
Glenn F. Hewitt, 4942 N. Kedzie Ave., Chicago, Ill.
Hobart F. Heller, James M. Coughlin High School, Wilkes-Barre, Pa.
E. A. Hollister, Pontiac H. S. and Junior College, Pontiac, Mich.
Eleutherio de la Garza, Brownsville, Tex.
E. L. Huber, Central High School, Lima, Ohio.
Harry Frye, Tullahoma, Tenn.
Warren R. Lange, 731 Lincoln Ave., St. Paul, Minn.
George E. Hudson, Room 1213, Navy Dept., Washington, D. C.

Perhaps some are acknowledged again. The worst of it is, I know I have missed the names of two or three! Apologies!!

KEEPING A PROMISE.

Here are Edison's Questions—complete. You know Edison picked some boys to go to college, expenses paid. The following promise was made to Miss Sylvia Erdman, Keno, Ore.:

Dec. 15, 1929.

Dear Miss Erdman:

I have just succeeded in getting hold of an official copy of Edison's Questions. I expect to publish them in the February number of School Science.

When you get them, won't you please try them out with your classes and send me the results with your own comments and the comments of the examinees?

Send me some of your own examinations or other material.

Examination, Edison scholarship award, West Orange, N. J., Aug. 1, 1929.

PHYSICS.

Answer Five Questions.

1. Define Work, Energy, and Power, and give an illustration of each. How does weight differ from mass? How does force differ from energy? Would a body weigh more or less on the moon than on the earth? Why? Where would bodies weigh nothing?
2. The specific heat of water is 1. and of mercury 0.033; the specific gravity of water is 1. and of mercury 13.6. For a foot warmer state which you would choose and why—a two quart hot-water bottle filled with water at 100°C. or a two quart flask of mercury at 100°C.
3. The specific resistance of an alloy is four times as great as that of copper. A copper wire 1000 feet long has the resistance of 40 ohms. How long a wire of the alloy having the same diameter as the copper wire would have the same resistance as the copper wire? Compared to the diameter of the copper wire what diameter of alloy 1000 feet long would have the same resistance as the copper wire?
4. The index of refraction of a glass is 1.5 and of another glass 1.7. If a biconvex lens of the same geometrical design was made of each of the two glasses, how would they differ optically? If they were placed in a transparent liquid of index of refraction 1.6 what effect would each have on a beam of light parallel to its principal axis?
5. The captain of a boat when passing a certain cliff on a summer night heard the echo of his whistle four seconds after blowing. How far away was the cliff? If he repeated this observation from the same point on a day in January would he notice any change in the time? If so, what and why?

6. The volume of an automobile tire is approximately 900 cubic inches and it is pumped up to a gauge pressure of 60 pounds per square inch. Its temperature is 20°C. Left in the sun its temperature increased to 35°C., and it exploded. What was the volume of the expanded air directly after the explosion? Could the pressure just prior to the explosion be computed from the above data?

CHEMISTRY

Answer Five Questions

1. When you read the names of the following persons, what fact is immediately associated with them in your mind?—Answer in one or two words in each case. Mendeleef, Davy, Perkin, Faraday, Curie, Priestley, Gay-Lussac, Dalton, Solvay, Ramsay, Lavoisier.
2. How would you prepare and collect in a reasonably pure state the following gases: (a) Nitrogen, (b) Ammonia, (c) Chlorine?
3. A set of bottles was known to contain the following powdered substances: Blue vitriol, ultramarine, manganese dioxide, carbon, potassium chloride and potassium chlorate, but the labels on the bottles have been destroyed. What tests would you apply, mental as well as physical, which would enable you to correctly and quickly relabel the bottles?
4. If you were nailing a copper sheathing on an exposed surface, what kind of nails would you use, and why?
5. Steel producing companies often have large quantities of ammonium sulphate for sale. How does the production of this substance happen to be connected with the iron industry?
6. Balance the following equation by inserting the proper coefficients. $AgNO_3 + Na2HPO_4 —— Ag_3PO_4 + NaNO_3 + HNO_3$.

MATHEMATICS

Answer Five Questions

1. Simplify: $\dfrac{1}{\dfrac{\sqrt{x+1-1}}{\sqrt{x+1}+1}}\left[\dfrac{(\sqrt{x+1}+1)\frac{1}{2}(x+1)^{-\frac{1}{2}}-(\sqrt{x+1}-1)\frac{1}{2}(x+1)^{-\frac{1}{2}}}{(\sqrt{x+1}+1)^{2}}\right]$
2. Solve: $\begin{cases} x^2-y^2=8 \\ xy=4 \end{cases}$
3. Assume the increase in any colony of mice to be such that the number doubles every three months. How large will the colony be at the end of three years if we start with a pair?
4. The acceleration of a body outside the surface of the earth is known to be inversely proportional to the square of the distance from the center of the earth. At the surface of the earth the acceleration is 32. What will the acceleration be fifty miles above the surface? The radius of the earth is 4000 miles. (Write answer in form of equation but need not simplify results.)
5. Without expanding, write the term containing X^{11} in the expansion of $(\sqrt{-X}-2X)^{18}$.
6. A triangle each of whose sides is 6 is divided into three equal areas by drawing two lines parallel to the base. Where will these lines intersect the altitude?

PART TWO

1. Outside of the field of religion, what three men, not now living, do you think particularly deserve your respect and admiration? What qualities do you admire in each?
2. What do you consider four of the most important qualifications necessary to success in any pursuit?
3. Which classes of books listed below do you most enjoy reading? Number them 1, 2, 3, et cetera, in the order of preference:

Adventure	Mystery Stories	Travel
Biography	Fiction	Invention
History	Economics	Science

4. If you could only read regularly four periodical publications (any kind), which four would you choose?
5. If you were marooned alone on a tropical island in the South Pacific without tools, how would you move a three ton weight, such as a boulder, 100 feet horizontally and 15 feet vertically?
6. If you had been given a certain experiment to perform and had been informed that it could be done successfully, but you had failed ten times, what would you do?
7. What new discovery or invention do you believe would be the greatest benefit to mankind? Why?
8. If you were to inherit $1,000,000 within the next year, what would you do with it?
9. What place in our daily lives do you think the automobile will have one hundred years from now?
10. If some acquaintance of yours unfairly accused you of cheating, what would you do?
11. What, if anything, does music mean to you beyond the usual reaction which most persons have to rhythm and melody?
12. When do you consider a lie permissible?
13. Two towns, on opposite sides of a river one mile wide, are cut off from communication with each other by any electrical means, due to a calamity. How would you attempt to establish communication between the two cities without the use of electricity? The river cannot be crossed by human beings.
14. Which one of the following would you be willing to sacrifice for the sake of being successful?

Happiness	Reputation	Honor	Money
Comfort	Pride	Health	Love

15. If there is a boy at your school whom you consider to be superior to you in intelligence and character, please write his name and address down here—

    ____

    ____

16. If you were on the verge of an important discovery and found the one missing link in another worker's laboratory, what would you do? Why?
17. Is the present relation of capital to labor reasonably fair?
18. Will you act as spokesman for the candidates when we meet Mayor Walker in New York City or would you prefer to let someone else do it? Why?
19. Why do you think you were chosen to represent your State in this competition?
20. Give a brief statement of what you hope will be a typical day for you when you are fifty years of age?

PART THREE

1. Assuming that you have just graduated from High School and are anxious to land a job—write a letter such as you would send to the Chief Engineer or to the President of the concern with which you would like to become connected. Assume that this letter is the only means open to you of securing the desired employment.

PART FOUR

1. What are the principal United States cities on the Atlantic Coast?
2. Who invented the cotton gin?
3. What did James Watt do?
4. Who wrote Treasure Island?
5. (a) Of what elements is common salt composed?

(b) What is the principal salt producing locality in the United States?
6. Why does this country honor Admiral Farragut?
7. What three very low forms of life can you name?
8. What is a mammoth?
9. Who was Jenny Lind?
10. What is a tourniquet?
11. (a) At what point on the Fahrenheit Thermometer does water boil? (b) On the Centigrade Thermometer?
12. On what physiological phenomenon is the success of motion picture projection dependent?
13. What is a meteor?
14. Name the use of the following:

Galvanometer	Pantograph
Vernier	Micrometer
Oscillograph	Pyrometer

15. What is the underlying principle of an internal combustion engine?
16. What is the function of the antenna in Radio?
17. What, in your opinion, should be done to improve the airplane?
18. Do Invention and Industry promote international agreement?

GENERAL SCIENCE EXAMINATIONS.

In answer to Question 542, lists of examination questions in General Science have been received from L. Paul Miller, Central High School, Scranton, Pa., and D. G. Vequist, St. Joseph, Mo.

Mr. Miller says:

Feb. 5, 1930.

Mr. Franklin T. Jones,
10109 Wilbur Ave.,
Cleveland, Ohio.

Dear Mr. Jones:

I have seen the call in SCHOOL SCIENCE AND MATHEMATICS for General Science questions, and am sending herewith our examination of last month. (Text used, "Our Surroundings," by Clement, etc.)

In our eight different semester examinations in four years of high school science, we are now experimenting with the plan of using completions, the missing word coming last in each statement. The words are written directly on the mimeographed paper. Drawings, calculations, etc., are done on the back of the sheet. I am enclosing also the Sr. A Chemistry examination of last month. (Text: Greer & Bennett.)

With this objective type of test, we feel quite safe in handing back his examination paper to each pupil, when he reports in his science class the beginning of the succeeding semester, and using it for review purposes.

I do not know that this system is especially original, but should like to hear what other science teachers think about it.

Very sincerely,

L. PAUL MILLER,
Head of Science Department, Scranton Central High School.

FR. A GENERAL SCIENCE (SECOND SEMESTER).

PART I. (Each statement counts two points.)

Write the missing words in the blank spaces, ON THIS PAPER. Hand in this paper only, at the close of the examination. USE PENCIL—NO INK. Think before you write. All words must be DISTINCTLY written, and properly spelled, to receive credit. Fold back paper along lines indicated, when you come to them. Answer PART II, on back of this paper.

Tides are caused by the pull of the ....
The 180 degree meridian is called the ....

Sound is transmitted through solids, liquids, and gases, not through ....

While we have winter, the southern hemisphere has the season ....
Sound passes fastest through (solids, liquids, or gases) ....
Fish in a bowl of water appear larger, because light is ....
In the normal eye, light rays are brought to a focus on the ....
Light (is or isn't) caused by vibration of air waves:
In a candle, or kerosene lamp, substance burning is first changed to a ....
Thomas A. Edison (is or isn't) an American inventor, still living:
Electric current used for lighting, in Scranton, comes from (dry cells, storage batteries, or dynamos:) ....
Electricity used in our homes is measured in units called ....
Telephone wires (do or do not) conduct sound waves when you phone:

FOLD PAPER BACK ALONG THIS LINE:

Sound waves (do or do not) travel from radio station to receiver:
President McKinley, in 1901, broadcast one of the first radio speeches, to be heard over 100 miles, as actual words. (True or False?) ....
The lever is a rod free to move about a ....
Working efficiency of a machine is reduced by ....
Power exerted by locomotives is due to the expansive force of ....
There (were or were not) steam locomotives in Civil War days:
There (were or were not) telegraph instruments in Civil War days:
There (were or were not) electric lights in the year 1901:
The first practical airplane was made by brothers named ....
Any object will float if it weighs less than an equal ....
The modern submarine was developed from inventions of ....
An airplane (did or did not) cross the Atlantic as early as 1919:
The throwing back of light rays from a smooth surface is called ....

FOLD PAPER BACK ALONG THIS LINE:

The process by which soil water is absorbed by plants is called ....
The raw materials used by plants in starch-making are: ...... and ......
When soaked seeds are placed in a jar containing a beaker of lime water, there is evidence of the presence of ....
When small seeds are planted in a glass container, and the jar tipped at an angle, the roots gradually turn down, due to ....
Four conditions needed for germination: (1) .... (2) .... (3) .... (4) ....
One method for holding water in the soil is ....
The sugar maple supplies us with: (1) .... (2) .... (3) ....
Edward Jenner's discovery has led to a common health regulation, which is: ....
Two plants used as food by man, and lower animals, are ...., ...
Seeds of the cacao tree supply us with: .... and ....
Disease germs may be carried by mosquitoes, by flies, and by ....
Insects render service in reproduction of plants, by carrying ....
The discovery of radium was made by ....
Radium (is or isn't) one of the essential materials in a radio broadcasting apparatus:

FOLD PAPER BACK ALONG THIS LINE:

PART II. (Each question counts five points.)

Answer all four of the following questions ON THE BACK OF THIS PAPER. Use pencil, no ink. Keep PART I face down. Unfold this paper when you hand it in.

(1) Make drawings of the large and small dipper, and locate the North Star.
(2) What causes a rainbow? Make a drawing to illustrate your answer.
(3) Make a drawing of the electric bell. Explain how it works.

(4) Describe in detail, an experiment to demonstrate osmosis. Draw a diagram of the apparatus, and label all parts.

SR. A CHEMISTRY (SECOND SEMESTER).

Write the missing words in the blank spaces, ON THIS PAPER. Hand in this paper only. USE PENCIL—no ink. Write DISTINCTLY. Think before you write. Allow 10 to 15 minutes for problems at end. When blank space is preceded by (f) ...., give a formula, otherwise, words.

The solid remaining after soft coal is heated, without air, is ....
The solid remaining after wood is heated, without air, is ....
Hard coal contains (more or less or same), uncombined carbon, as compared with soft coal: ....
Graphite and diamond are both forms of carbon known as ....
The formula for the dangerous gas in exhaust from autos is (f)
The name of the acid with the formula H_2CO_3 is: ....
This acid differs from sulphuric and tartaric in that it is ....
All carbonates are insoluble except: sodium, potassium, and ....
To test for a carbonate, add to the unknown, any ....
In above reaction, unknown is a carbonate, if gas liberated will ....
In ethane, of the methane series, the two carbon atoms are united by (1, 2, 3, or 4) .... bonds.
The highest members of the methane series are (gases, liquids, solids) ....
Molecular formula for butane, 4th member of methane series, is (f) ....
An inflammable liquid used at a cleaning agent is: (benzine, benzene) ....
The formula for chloroform is $CHCl_3$. Formula for iodoform is (f) ....

FOLD PAPER BACK ALONG THIS LINE:

Fire damp in mines is an explosive mixture of air and ....
Washing soda in solution turns litmus paper (red, blue, neither) ....
All baking powders contain starch, and the compound (f) ....
The flash point of gasoline is (lower, higher) than of kerosene ....
Natural gas consists mostly of the gas whose formula is (f) ....
Water gas consists mostly of the two gases, (f) .... and (f) ....
For every pound of carbon which burns completely, in your furnace, ... pounds of oxygen are used, from the air, and .... pounds of carbon dioxide go up the chimney. (C, 12. O, 16.) USE OTHER SIDE.
When acetylene burns completely, two cubic feet of acetylene and .... cu. ft. of oxygen combine; the number of cu. ft. of OO_2 formed, is: ....
The formula for ethyl alcohol is (f) ....
Ethyl alcohol to which poisons have been added is said to be ....
Alcohols (do or do not) turn litmus paper blue: ....
Sucrose, or granulated sugar, has the formula: (f) ....
Oils and fats are formed by the action between fatty acids and ....

FOLD PAPER BACK ALONG THIS LINE:

Give formulas for left and right sides of equations, for these reactions:
Copper oxide plus carbon: (f) ....
Calcium carbonate, heated: (f) ....
Calcium oxide, plus water: (f) ....
Calcium carbonate, plus hydrochloric acid: (f) ....
Carbon dioxide, plus $Ca(OH)_2$: (f) ....

Five reactions for (1)	(2)
making washing (3)	
soda, by the	(4)

Solvay process: (f) (5)
Sodium bicarbonate plus
$KHC_4H_4O_6$: (f)
Complete equation: $C_3H_5(OH)_3$ plus 3 $HC_{17}H_{33}COO$ yield
$C_3H_5\ (C_{17}H_{35}COO)_3 + NaHSO_4$ plus
hydrochloric acid: (f) ....
FeS plus 2HCL yield (f) .... plus (f) ....
Cadmium chloride plus hydrogen sulphide: (f) ....
Copper plus cold
dilute nitric acid: (f) ....

FOLD PAPER BACK ALONG THIS LINE:

In solving the following two problems, SHOW ALL CALCULATIONS on the back of this paper. Ca,40. C,12. O,16. N,14. H,1. CL, 35.5

1. Two hundred grams of calcium carbonate react with sulphuric acid to produce .... g. of carbon dioxide gas.
2. One hundred pounds of ammonium chloride react with sodium hydroxide, to produce .... lb. of ammonia gas.

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS, INC., 29TH ANNUAL MEETING.

The annual meeting of the Central Association will be long remembered for its large attendance, its splendid programs, and the exceptionally fine facilities which were provided by the University of Chicago. It represented the climax of a very active association year under the able administration of Miss Ada L. Weckel as President.

In spite of the cold weather the Friday morning program opened at Mandel Hall with a very good attendance. The program was as follows: Organ Recital—9:15-9:30. James W. Hoge, University High School, The University of Chicago. Address of Welcome—Dr. Robert M. Hutchins, President of The University of Chicago. Response for the Association—Walter G. Gingery, George Washington High School, Indianapolis, Ind. Address—Prof. Arthur H. Compton, The University of Chicago. Subject: What Things Are Made of. Address—Prof. M. F. Guyer, The University of Wisconsin. Subject: Democracy, A Biological Problem.

The address by Prof. Compton, a Nobel prize winner, was most scholarly and interesting. His presentation of atomic structure was liberally illustrated with photographic evidence.

Prof. Guyer showed with remarkable clearness that to be well born is not only an important need of the individual but is equally essential for the highest type of a democracy. His conclusions emphasized the enormous influence which biological human relations have on national welfare.

Most of the section meetings held in the afternoon were well attended. The Chemistry section was smaller than usual, while the Geography section was larger than for several years past. A feature of all section meetings was a discussion on the topic: "What do you want in the Journal?" Many very helpful suggestions were presented and these were transmitted to the Journal Committee. The Biology, Mathematics and Physics sections benefited by speakers who also appeared on the general programs. Four of the speakers at section meetings came a long distance. These were Mr. Howard C. Kelly, Springfield, Mass., Prof. N. Henry Black of Harvard University, Prof. Duane Roller of the University of Oklahoma, and Prof. Dunham Jackson of the University of Minnesota.

The annual dinner held at Ida Noyes Hall was well attended. A splendid meal was served and good cheer was added to it by the music of some accomplished radio artists. After the meal the audience repaired to the Little Theater where Dr. William M. McGovern of Field Museum and

Northwestern University gave a most original, graphic, and authoritative lecture on Asia in World History. He showed that the early history of Asia is directly related to many phases of American history.

The program on Saturday morning was as follows: Organ Recital—9:30-9:45. James W. Hoge, University High School, Chicago, Ill. Address—Prof. Dunham Jackson, University of Minnesota. Subject: Statistical Application of Elementary Mathematics. Address—Prof. N. Henry Black, Harvard University. Subject: Training of Science Teachers Here and Abroad. Address—Dr. Frank T. Gucker, Jr., Northwestern University. Subject: Measuring the Millionth of a Centigrade Degree to Test Modern Scientific Theories.

Professor Jackson gave a very interesting address, which is published on another page of this issue.

Prof. Black made a number of helpful suggestions and submitted a short reading list for science teachers. He showed that general science teachers should have the habit of wide reading. In foreign countries the academic training of all teachers is great; practice teaching is considered indispensable; and science teachers are specially trained to give demonstrations.

Prof. Gucker showed that the infinitely small unit in heat energy has scientific significance just as the infinitely small units in matter have helped to solve the mystery of the atom.

The success of this annual meeting was due to many helpful contributions including not only the efforts of officers, committees and speakers but the enthusiasm of the attending members as well. The many and extensive exhibits were an impressive feature; the cordial manner in which exhibitors assisted in receiving those in attendance added much to the general cheerful atmosphere; much helpful information was dispensed at the same time. The favorable space and other facilities for these exhibits was arranged under the able direction of Mr. O. D. Frank. For the splendid arrangements of all local matters including all privileges on the University Grounds, Mr. J. C. Mayfield deserves special credit. For the large number of new members who registered we are especially indebted to Miss Villa B. Smith, who as chairman of the Membership Committee carried on most commendable publicity work for the Association.

As the meeting adjourned it was the unanimous opinion that a very large part of the success was due to the excellent meeting place provided by the University of Chicago and the friendly cooperation given by its President and Faculty. For this the Association expresses its deep appreciation.

Respectfully submitted,

W. F. Roecker,

Secretary.

REPORT OF THE COMMITTEE ON PROFESSIONAL TRAINING.

The training of high school teachers is one of the major problems in education. A complete statement of the problem would be desirable but could not be included in this report. Your committee has, therefore, limited its considerations to matters that have a direct bearing upon the training of science and mathematics teachers for secondary schools.

It is not uncommon for some of our best teachers of science and mathematics to attribute their success to the inspiring influence of the personalities and methods of some well-known College or University professors under whom they received a part of their academic instruction. The

concrete examples of these master minds who are devoting much of their time to research but who also know how to teach are perhaps the most potent factors in the training of superior high school teachers. Society owes a debt of gratitude to these great leaders in education. On the other hand, however, it is a distinct social loss for teachers in training to do their academic work in departments in which the emphasis upon research interferes seriously with good teaching. The prospective teachers may obtain a knowledge of subject-matter but they form low ideals of teaching which they carry with them into their high school work. These conditions are not peculiar to the academic departments. They are known to prevail also in the departments in which the teachers receive their professional training.

A difficult problem that has developed in recent years pertains to the relative amount of time that should be devoted to academic and professional work. Which kind of work will make the largest contribution in the preparation of high school teachers? The leaders themselves do not agree. Consequently the quickest way for them to solve the problem is to appeal to state legislatures or to standardizing agencies. In this respect the leaders in professional subjects have been more successful than the leaders in academic subjects. This is no doubt due to the fact that the latter have made practically no effort to influence these bodies. We find, therefore, that while the various states differ widely in their requirements for academic and professional training, the professional requirements are always much higher than the academic requirements. As a result there are teachers of science and mathematics who are not properly prepared to teach these subjects. Standardizing agencies are beginning to recognize this fact. The North Central Association of Colleges and Secondary Schools took an important step at its last annual meeting. One of its standards which specifies that teachers shall teach only in their major and minor subjects now includes the further provision, that a minor shall consist of a minimum of ten semester hours. This body requires fifteen semester hours of professional work.

We must remember, however, that quantitative standards alone do not determine the real training that teachers receive. The nature of the courses and the qualifications of the instructors are equally important. The number of courses in education is rapidly increasing. It is self evident that they do not all have the same value in the preparation of teachers for their professional duties. Again some courses are duplicates, in part, and the numerical requirements may be met without having covered a wide range of material. In the academic subjects these difficulties do not, as a rule, prevail.

The prospective teachers may complete the required number of academic and professional courses and still be unable to begin their work satisfactorily There should be courses available in the teaching of high school subjects and in practice teaching It is very important, however, that these courses be taught or supervised by instructors who know both subject-matter and methods of teaching This may be difficult to obtain but it is essential to the best preparation of the teacher.

There are organizations that have devoted considerable time to the solution of these problems. They should have the support of all educational organizations that are either directly or remotely interested in the proper training of high school teachers. Our own organization can play an important part in this work by cooperating with these bodies and in securing the cooperation of others to promote the welfare of the teachers of science and mathematics in the high schools.

It is recommended therefore and I move

1. That the recommendations of this committee adopted at our last annual meeting be reaffirmed.

2. That we encourage and aid in promoting any movement that will enable prospective teachers in science and mathematics in the high schools to secure their training under instructors who have been secured because of their recognized abilities to teach as well as to do research work.

3. That we urge all standardizing agencies to give due consideration to the academic work in their minimum requirements for teacher-training work.

4. That we encourage and aid in promoting any movement that will tend to withhold professional credit for duplicate courses or courses that do not have a direct bearing upon the training of teachers.

5. That courses offered in the teaching of high school subjects or in practice teaching be taught or supervised by instructors who have been trained in subject-matter as well as in methods in teaching.

6. That the Board of Directors or Executive Committee be authorized to appoint the proper body to promote these recommendations.

Respectfully submitted:

E. W. Owen,
Robert N. Aufle,
Sarah A. McEvoy,
Winnafred Shepard,
G. W. Warner.
J. M. Kurtz,
Chairman.

BOOKS RECEIVED.

Educational Biology by W. L. Eikenberry, Professor and Head of the Science Department, Trenton Teachers College, Trenton, New Jersey, and R. A. Waldron, Professor and Head of the Science Department, State Teachers College, Slippery Rock, Pennsylvania. Cloth. Pages viii+549 12.5x19.5 cm. 1930. Ginn and Company, 15 Ashburton Place, Boston, Mass. Price $2.48.

Solid Geometry by William W. Strader and Lawrence D. Rhoads of the Wm. L. Dickinson High School, Jersey City, New Jersey. Cloth. Pages viii+170+5. 12x18.5 cm. 1929. The John C. Winston Company, Winston Building, 1006-1016 Arch Street, Philadelphia, Penn. Price $1.20.

Second Course in Algebra by Fred Engelhardt, Professor of Education, University of Minnesota and Leonard D. Haertter, Head of the Mathematics Department, John Burroughs School, St. Louis, Missouri. Cloth. Pages viii+423. 12x18.5 cm. 1929. The John C. Winston Company Winston Building, 1006-1016 Arch Street, Philadelphia, Penn. Price $1.36.

The Making of Chemistry by Benjamin Harrow, Assistant Professor of Chemistry at the College of the City of New York. Cloth. Pages viii+223. 12.5x19 cm. 1930. The John Day Company, Inc., New York. Price $2.00.

The Problem and Practice Arithmetics, Third Book, by David Eugene Smith, Teachers College, Columbia University, Eva May Luse, Iowa State Teachers College and Edward Longworth Morss, Editor of Mathematical Textbooks. Cloth. Pages vii+496. 12x18.5 cm. 1930. Ginn and Company, 15 Ashburton Place, Boston, Mass. Price 88 cents.

The Calculus by Hans H. Dalaker, Professor of Mathematics and Mechanics, University of Minnesota and Henry E. Hartig, Electrical Engineering Department, University of Minnesota. Cloth. Pages viii+254. 14.5x23 cm. 1930. McGraw-Hill Book Company, Inc., 370 Seventh Avenue, New York. Price $2.25.

The Story of Evolution by Benjamin C. Gruenberg. Cloth. Pages xvi+473. 15x22 cm. 1929. D. Van Nostrand Company, Inc., Eight Warren Street, New York. Price $4.00.

Problems of Science Teaching at the College Level by Archer Willis Hurd, Research Associate, Teachers College, Columbia University. Cloth. Pages xviii+195. 14.5x23 cm. 1929. University of Minnesota Press, Minneapolis, Minn. Price $2.00.

Insect Ways by Clarence M. Weed, Principal of the State Normal School, Lowell, Mass. Illustrated. Cloth. Pages vii+343. 12.5x19 cm. 1930. D. Appleton and Company, 35 West 32nd Street, New York. Price $1.36.

Vocational Mathematics by Edgar M. Starr and Edwin G. Olds, Assistant Professors of Mathematics in the Carnegie Institute of Technology. Cloth. Pages x+184. 13x19.5 cm. 1930. P. Blakiston's Son and Company, Inc., 1012 Walnut Street, Philadelphia, Penn. Price $1.25.

Safety Education in the Secondary Schools by Herbert James Stack, Associate Professor of Education at Pennsylvania State College. Paper. Pages vi+157. 15x23 cm. 1929. National Bureau of Casualty and Surety Underwriters, New York.

Exercises and Problems in Elementary Economic Geography by W. O. Blanchard, Associate Professor of Geography, University of Illinois. First Edition. Paper. Pages vii+48. 21.5x27 cm. 1930. McGraw-Hill Book Company, 370 Seventh Avenue, New York. Price $1.00.

A Guide for the Study of Plants by Mabel E. Smallwood, Department of Biology, Lane Technical School, Chicago, Ill. Paper. Pages vi+97. 20x27.5 cm. 1929. D. C. Heath and Company, 285 Columbus Avenue, Boston, Mass.

BOOK REVIEWS.

The Fundamentals of Radio by R. R. Ramsey, Professor of Physics, Indiana University. Cloth. Pp. xi+372. Ramsey Publishing Company, Bloomington, Ind. Price, $3.50.

Those who are familiar with Professor Ramsey's Manual of Experimental Radio will be greatly pleased with this new book which is intended to accompany the manual.

The book is intended for use in first year college classes. The student is assumed to have an elementary knowledge of electricity such as is usually given in a first year course in Physics.

The Fundamentals of Radio is written as a nonmathematical treatment of the theory of radio as it is exemplified in modern practice. In the few places where it has been necessary to introduce Calculus the sections dealing with it have been developed and explained in such a way that very little difficulty should be experienced by first year college students.

The book is largely based upon the two conceptions, the resonant or wave meter circuit and the three electrode vacuum tube. It is divided into thirty chapters, the first four of which deal with the measurement of resistance and the fundamentals of direct and alternating currents. The student is then introduced to the resonant circuit as the basic principle of radio.

An interesting feature of the book throughout is that very little space has been devoted to obsolete apparatus, which is of historic value only. All illustrations and discussions of apparatus are of that which is in actual use today.

The treatment of vacuum tubes is especially clear.

A. E. Jeffrey.

Science Teaching. What It Was—What It Is—What It Might Be, by F. W. Westaway. Blackie & Son, Limited, London and Glasgow. 1929. Pp. xxii+442.

This book was written by an English Inspector of Secondary Schools

who admits that he has been present at something like 1,000 lessons a year for over 30 years. One does not read far before being impressed with the fact that it is not only so useful a book that every science teacher should have access to it, but that it is written in an unusually fresh and breezy style. In fact the book is decidedly interesting and shows the practiced hand of an author who has written other books: "Scientific Method," "Science and Theology," and "The Writing of Clear English."

It is divided into four parts: I. *Some principles of science teaching.* II. *The different subjects of instruction.* III. *Extended considerations for sixth forms.* IV. *Accommodation and equipment.* Since the book is intended for English science teachers, the American teacher is at once struck by the difference in conditions which prevail in English and American schools. For example, the teaching of general biology in English schools seems to demand special arguments for its very existence, and our so-called general or elementary science course for the seventh, eighth, and ninth grades is not even discussed. Hence Westaway's book will interest chiefly the teachers of physics and chemistry. It is also a bit disappointing that the author seems so completely unaware of modern American books on teaching science and is evidently unfamiliar with our textbooks of science, our laboratory manuals, and our laboratory equipment. These omissions are a good argument for more interchange of ideas between the science teachers of this country and Great Britain.

Evidently the science teacher who is beginning his career is the person for whom this book is written. It is packed full of practical advice without being in any way dogmatic. For example, in discussing the marks of a successful science teacher, he says:

"He (the successful science teacher) knows his own special subject through and through, he is widely read in other branches of science, he knows how to teach, he knows how to teach science, he is able to express himself lucidly, he is skilful in manipulation, he is resourceful both at the demonstration table and in the laboratory, he is a logician to his finger-tips, he is something of a philosopher, and he is so far an historian that he can sit down with a crowd of boys and talk to them about the personal equations, the lives, and the work of such geniuses as Galileo, Newton, Faraday, and Darwin. More than all this, he is an enthusiast, full of faith in his own particular work."

If there were space, one might quote much from this interesting book. A list of a few chapter headings will indicate the scope of the book: Self-training; Laboratory directions, bad and good; A common cause of failure; The content of the normal science course: Syllabuses and schedules of work; Science teachers as teachers of English; Biological by-ways; Science in rural schools; The structure of the atom; Relativity; The very great and the very small; Research: its significance and importance; The philosophic foundation of science; Science and humanism; Laboratories and equipment; Science libraries. The book closes with a six-page Appendix which contains three sets of questions: one for boys leaving school, another for young science teachers, and a third on methods of teaching science.

N. Henry Black.

Introduction to Physical Optics by John Kellock Robertson, Professor of Physics, Queen's University, Kingston, Canada. Cloth. Pp. vi+422. 13x21 cm. 1929. D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York. Price $4.00.

In contrast to many courses of study there is a decided dearth of good text books in the field of physical optics that are suitable for a beginning class in this subject. This gives a new book the advantage of less competition but demands more originality in method of presentation by the author. In this Professor Robertson has shown rare ability. He assumes that the students who use the book as a text

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have retained very little knowledge of the subject from previous study. The introductory chapter reviews some common light phenomena and states briefly the two theories of light. This is intended to show the necessity for the careful study of wave motion which follows.

The chapter on wave motion may be taken as a sample of the clear presentation throughout. Drawings, graphs, numerical illustrative problems with tabulated data and complete solutions, combine with explanatory paragraphs to produce a simple, thorough treatment of the subject. A rather long list of problems with each chapter provides plenty of practice material. In the discussion of mirrors and lenses both ray and wave front diagrams are used but all laws are developed from a consideration of waves. All through the discussion of the common phenomena—reflection, refraction, dispersion, interference, etc., the wave theory is used as the basis for explanation.

Descriptions of classical experiments and of instruments that apply optical laws are used to supplement the discussions of general principles. These departures from pure theoretical treatment assist in holding the interest of students of other branches of science who need a working knowledge of optics. The author's ability to sense the difficulties of students is well shown in his discussion of the case in which a square term is neglected in making an approximation when the term involved is small. Here again the situation is made clear by a complete computation, thus showing the student the actual error in a particular case.

Special mention needs to be made of the very excellent chapters on double refraction and polarization. Chapter XVII really introduces the more recent developments in the subject and provides a natural introduction to the brief discussion of the quantum theory and the ether controversy. The two final chapters headed The Dilemma and Can The Existence of An Ether Be Detected? give briefly the latest developments and leave the students eager for the next chapters still in the making in the research laboratories. G. W. W.

The Terminology of Physical Science by Duane Roller, assistant professor of physics in the University of Oklahoma. University of Oklahoma Press. 1929. Pp. 115. $1.00.

Dr. Roller's contribution to scientific literature is an outcome of his belief (a belief shared by many educators and scientists) that scientific terminology is an important means but not an end in itself, and that its problems are, therefore, for the teacher and text book writer and not for the elementary student. The subject matter in his book is classified into six chapters, the respective titles of which give an excellent idea of the contents. They are as follows:

I. Physical terms and their definitions.
II. Common prefixes and suffixes.
III. The names of chemical elements.
IV. The pronunciation of words used in science.
V. The spelling of words used in science.
VI. Simpler standard abbreviations.

In the first chapter which constitutes, I believe, the backbone and the most original part of the book, the author makes a critical analysis of the terms used in the text books. He classifies them into two groups (1) terms and expressions that should be discarded, and (2) terms requiring careful definition or special comment. The reviewer believes that a careful study of the analysis presented by Dr. Roller should be of great help to the teacher and scientific writer.

The chapter on the pronunciation of words used in science, which includes the topics of teaching pronunciation, standards of pronunciation, proper names, common mistakes, and words commonly mispronounced, brings within the space of a few pages, not only a number of good suggestions, but also answers to many of our doubts.

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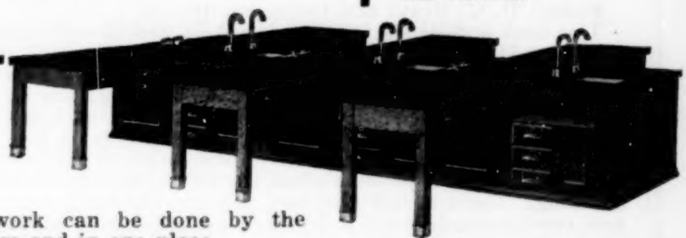

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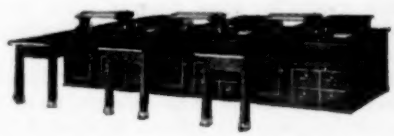

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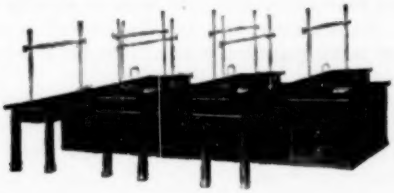

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In summing up, although some of the suggestions concerning the terms to be dropped and changes in spelling may be thought rather drastic, and although some slight mistakes concerning the etymology of a few words have crept in, I believe that the book, on the whole, points in the right direction and that the definitions of various scientific terms and words have been intelligently and carefully chosen.

Ph. A. Constantinides.

Modern Algebra, Third Semester Course, by Webster Wells, S. B., Author of a Series of Texts on Mathematics, and Walter W. Hart, A. B., Associate Professor of Mathematics, School of Education, and Teacher of Mathematics, Wisconsin High School. Pp. vii+266. 14.5x19.5 cm. 1929. $1.32. D. C. Heath and Company, Boston.

This book is designed to follow the Wells and Hart Modern First Year Algebra. It embodies many features that make it truly modern. For example, the graph is not isolated by setting it off in a separate chapter, but is made an integral part of the text. It is used to express functionality, display solutions of equations, and to depict various other abstract situations. In the chapter on quadratic equations we find the "Theory of Quadratics" follows immediately the solution of the general equation. This order makes it possible to use the root sum and product formulas in checking. The first four chapters, and also the sixth and seventh chapters, contain much material that is found in first year work. This material, however, need not be worked over by students, or classes, who are able to pass the numerous diagnostic tests that are provided.

Abundant topics and problems are provided to take care of students of various shades of ability. The author has provided a teachers' handbook which offers suggestions in regard to the handling of the optional material. We find many chapter-mastery tests, cumulative reviews, and practice exercises.

Considerable attention is given to functionality. This notion is developed explicitly in Chapter V and is used frequently throughout the text.

J. M. Kinney.

SAMPLE BLOCKS OF COMMERCIAL TREES.

In response to a demand from schools and colleges for typical specimens of the commercial woods of the United States, the National Lumber Manufacturers Association has provided 500 sets, each containing finished blocks typical in grain and texture, of 40 different species of woods. The sets will be distributed to institutions that are likely to make the best educational use of them, at cost of production.

"Many schools that have been anxious to have these wood specimens for studies in natural history, raw material sources, and like courses, have found in the past that it has been difficult and impracticable to attempt to build up individual collections," said Walter F. Shaw, manager of the Association's trade extension work. "Also, some of the prepared sets available have been a little more expensive than many schools, with limited means and many calls on their resources, have felt they could afford. Study of the woods that we meet in every day life is a distinct advantage for students. Also, since such woods are mostly commercial woods, it is an advantage to the lumber industry to have their qualities generally known, so that the public will appreciate native woods and will have some selection background to insure their getting the best out of the woods they use. Accordingly, the Association felt it advisable to make such sample boxes more popularly available for schools, high schools and colleges."

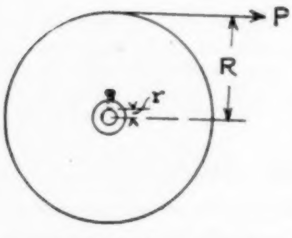
The block sets are packed in a handy size slide-cover wooden box ten inches long, seven inches wide and six inches deep that may be kept on a school desk or table or in a specimen cabinet. Each of the forty blocks is

labeled with a legend identifying the species, telling the approximate amount of such lumber produced annually, the native regions of growth, the particular and peculiar qualities of the species, the varied uses to which it is customarily put, and the names of the regional associations to whose grading rules the principal manufacturers of such woods subscribe. Each block is 2¼x⅝x5 inches, and is cut so that the color and graining of the wood and, where possible, the cell structure, can be shown to the best advantage.

The National Lumber Manufacturers Association formerly had available a rack display of thirty-two species, which was more expensive to distribute. It is expected the new and more comprehensive sample sets can be distributed at a cost of two dollars a set. The Association offices in Washington, D. C., should be addressed by interested school officers or by lumbermen who would like to make gifts of the sets to their local schools.

WHY SET SCREWS SLIP.

By W. F. Schaphorst, M. E.,
45 Academy St., Newark, N. J.



After a set screw slips, no amount of tightening will prevent slip if the set screw is too small. A slipping set screw is either too small or it is not tightened sufficiently.

Set screws are commonly called upon to pull entirely too much. It is amazing what is expected of them. When you consider that belt pull P as shown in the accompanying sketch is usually in the hundreds of pounds and often in the thousands of pounds and when you consider the great leverage it generally has on the set screw, the wonder is that set screws do not slip more than they do.

To compute the force that a set screw must resist, proceed as follows:

(1) Multiply the horse-power by the radius R in inches and then multiply by 33,000.

(2) If it is a belt drive, multiply the velocity of the belt in feet per minute by the radius r in inches.

(3) Divide (1) by (2) and you have the force in pounds that the set screw must resist.

If it is a gear or chain transmission, the same rule applies. The principal factors that need be known are, as enumerated above, the horse-power; the velocity of the belt, chain, or pitch circle of the gear; the radius R; and the radius of the shaft, r.

After knowing the force that the set screw must resist the following rule will be found useful to make certain that the set screw is large enough: Extract the square root of the force in pounds and divide by 40. The result is the diameter of set screw in inches.

If you want greater refinement use this table.

d (in.) =	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1-1/8	1¼
P (in.) =	100	168	256	366	500	658	840	1280	1830	2500	3288	4198

Thus, for example, if you get 2400 lb. as the answer, a one inch set screw will be required according to the table. Or, two set screws, each 3/4 of an inch in diameter. The rule gives a set screw 1¼ inches in diameter.

WATER POWER OF THE COLORADO.

The water resources of the Colorado River and its tributaries constitute the most valuable asset of a large part of the West and Southwest. With a view to determining the location, magnitude, and value of these resources, the Interior Department, through the Geological Survey, has for many years been carrying on investigations within the drainage basin of the river. Publications dealing with different parts of the basin have been issued from time to time, and the latest is Water-Supply Paper 617, entitled "Upper Colorado River and its utilization" by Robert Follansbee, which has just appeared. This paper, an elaborate report of nearly 400 pages which may be obtained from the Superintendent of Documents, Government Printing Office, for 65 cents, embraces the part of the drainage basin above the Green River.

The drainage area of this part of the basin is 26,500 square miles, which is 1 per cent of that above Lees Ferry, Ariz., the point that makes the dividing line between the upper and lower basins as defined by the "Colorado River compact," and the mean annual run-off is 6,600,000 acre-feet, or 45 per cent of that at Lees Ferry.

The report shows that in the area described about 564,000 acres is irrigated at present and that within possibly the next 50 years this area may be increased to 1,230,000 acres. The irrigation of the additional land will reduce the mean annual run-off by about 1,000,000 acre-feet.

The developed water power in this area amounts to 47,352 horsepower divided between 41 plants. A historical sketch of this development discloses the fact that the first hydroelectric plant in the United States to transmit alternating current at high voltage for the purpose of operating a motor at a considerable distance is within this part of the Colorado River basin. This is the famous Ames plant, near Telluride, built about 1890. Another plant built about 1888 in this area was apparently the first in the world to operate an electric hoist for mining.

At 40 sites in the part of the basin above the Green River undeveloped power amounting to 117,000 horsepower for 90 per cent of the time or 222,000 horsepower for 50 per cent of the time has been considered. By the construction of storage reservoirs these totals would be increased to about 300,000 and 400,000 horsepower respectively.

Transmountain diversions of water out of this part of the Colorado River basin now amount to 20,000 acre-feet annually, which may be increased to 300,000 acre-feet if additional projects described in the report are developed.

"To be honest, to be kind, to earn a little and to spend a little less, to make upon the whole a family happier for his presence, to renounce when that shall be necessary and not be embittered, to keep a few friends, but those without capitulation—above all, on the same given condition to keep friends with himself—here is a task for all that a man has of fortitude and delicacy."—Robert Louis Stevenson.

Our great advance in material prosperity can be ascribed in part to the higher educational levels and thinking to which the work of the public schools has raised the masses.—Roger W. Babson.